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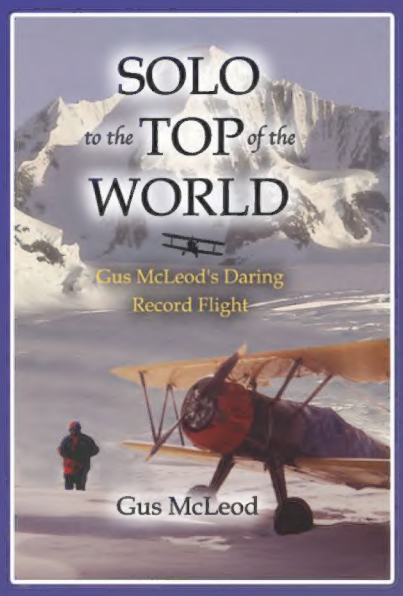

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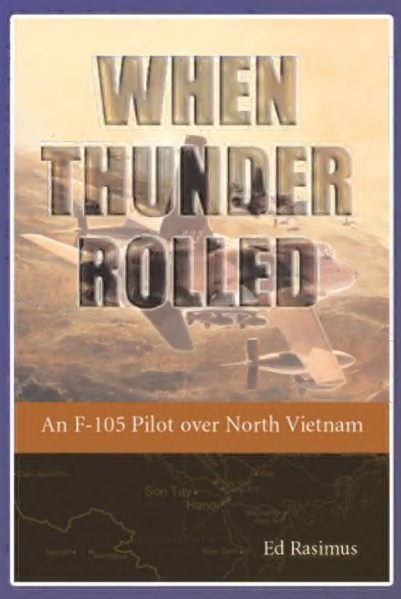

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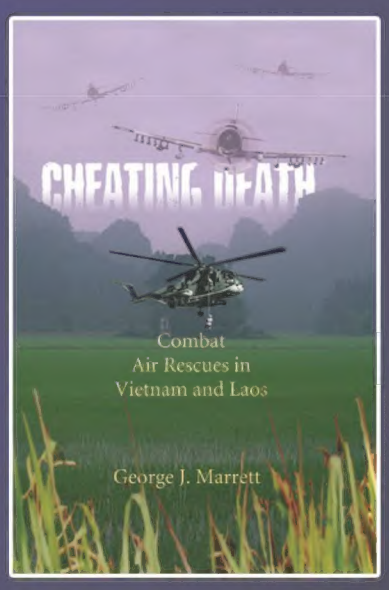

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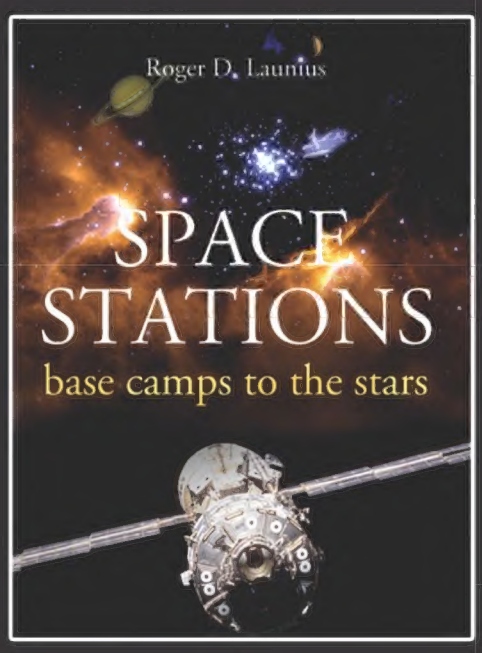

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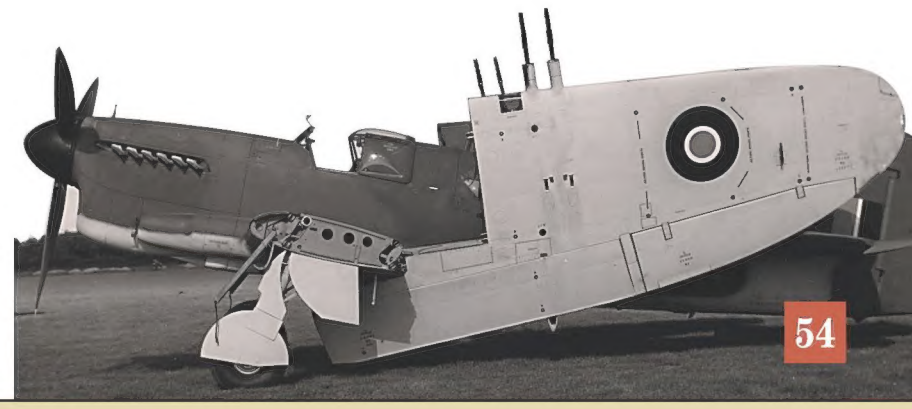
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Poetry in motion. In Chad Slattery's portrait of a Fairchild PT-19 trainer, the vintage whir is courtesy of the Sensenich Brothers Propeller Company.

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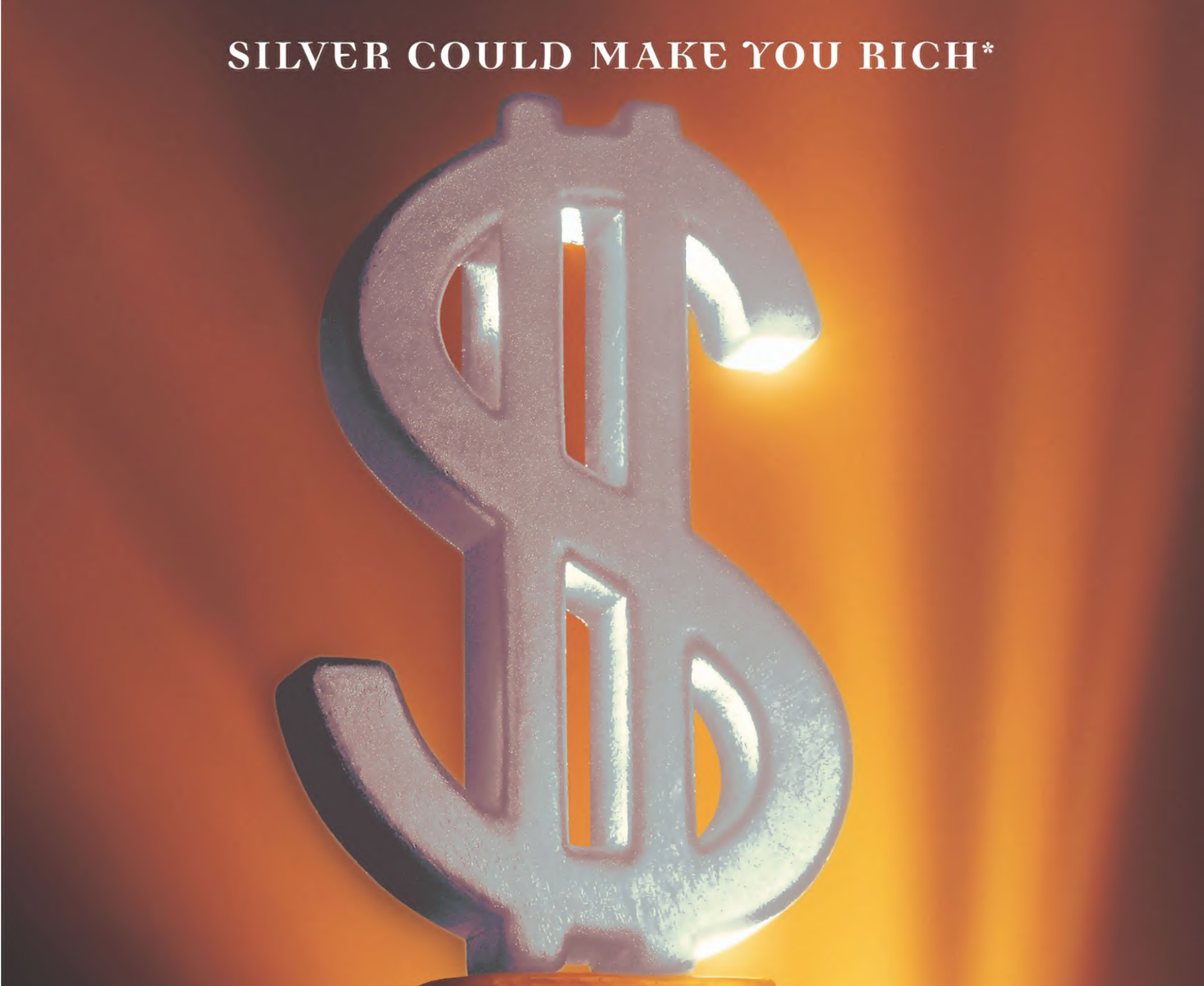

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Our art collection has its own history: Paul Garber, who pioneered the display of aircraft at the Smithsonian, was the son of an art dealer, and he insisted that works of art be a part of the National Aeronautical Collection. The legislation authorizing the construction of a museum for air- and spacecraft required that an art gallery be included in the building plan and also established an art unit headed by a staff curator. James Dean, the artist and administrator who had played a key role in the creation of the NASA art program, became our first curator of art in 1974 and brought the NASA art collection to the Museum.

Today, our art collection includes over 4,100 works: paintings, drawings, lithographs, sculptures, textile pieces, and decorative arts items—all reflecting aerospace themes. The collection includes masterworks by R.G. Smith, Frank Wootton, Keith Ferris, William Phillips, Ted Wilbur, and Robert Taylor, who capture the history of aviation. Robert Rauschenberg, Peter Hurd, Norman Rockwell, and James Wyeth give us the excitement of the space age.

Others look to the future: Chesley Bonestell, Robert McCall, Ludek Pesek, Ron Miller, Andrei Sokolov, David Hardy and others who share their vision help us to imagine what it would be like to live and work in space and stand on the surface of other worlds.

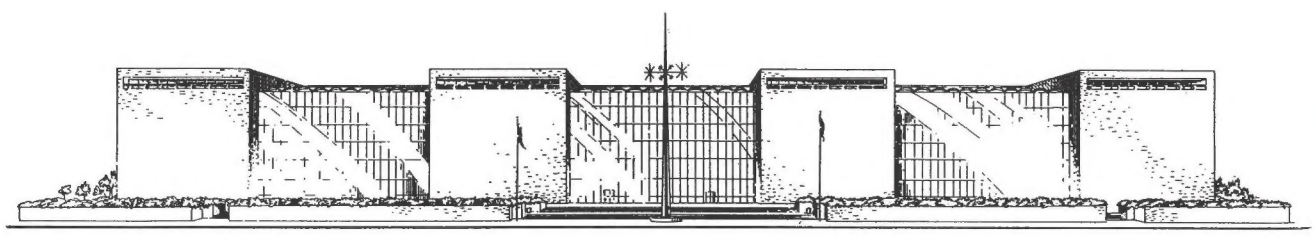
Among the works that have become great favorites are two large murals by Robert McCall and Eric Sloane, which have served as the background for countless family snapshots in the lobby; "Fortresses Under Fire," the stunning Keith Ferris mural, dominates the World War II gallery. Then there are the three pieces of outdoor sculpture that have framed our building on three sides since 1976: "Delta Solar" by Alejandro Otero, Richard Lippold's "Ad Astra," and "Continuum" by Charles Perry.

A 70-foot-high John Safer sculpture will grace the Steven F. Udvar-Hazy Center at Dulles airport in Virginia when it opens in December, along with some unique decorative arts, many of which date back to the 18th century, when the invention of the balloon inspired furnishings, jewelry, ceramics, and fabric decorated with balloons.

Soon art will have an even larger presence in the Museum on the Mall. The Museum's art gallery was closed some years ago during renovation of the building. Since that time we have worked hard to continue making our collection accessible, displaying art in other parts of the Museum, increasing our loan program, and participating in traveling exhibitions.

Our plan is to reopen the traditional art gallery in 2004 or 2005 with an emphasis on works from our permanent collection. The artistic vision can spark appreciation for the impact of flight on the world. All of us look forward to the reopening of a permanent home in which to share these riches.

—J.R. Dailey is the director of the National Air and Space Museum.



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LETTERS

Of Questionable Origin

To Bill Sweetman's parallels between the evolution of living organisms and that of airplanes ("How the 747 Got Its Hump," Apr./May 2003), I would add one more. In his book *Wonderful Life*, which recounts the reinterpretation of the Burgess Shale fossil deposits, the late paleontologist Stephen Jay Gould makes the point that all phyla (major body types), including our own, Chordata, appeared during a relatively short period. No new phylum has been created since.

This stands to reason. When the first multi-cellular animals appeared, all of the ecological niches were essentially empty, and many body types evolved to exploit them. During this period it was more important that something worked at all than that it worked well. Consequently, there was a lot of variation.

Once all of the niches were filled, competition set in and became the primary means of selection. In this phase, it is important to work well and adapt well. Some phyla were better suited to competition than others. Some died out.

In aviation, much the same thing has happened: Within the first few decades, many variations were tried, and slowly a few major phyla came to predominate. Some of the lesser ones found specialized niches, but they never regained the size and stature of their heyday.

John Day
Foxboro, Massachusetts

I found the last line of Sweetman's article, "...and that is why evolution rules, in aviation as well as in nature," nearly as whimsical as Harry Whitver's excellent illustrations.

In any project, every time a tornado hits a junkyard, in the form of new consumer demands, new government regulations, or mission alterations, it takes a team of educated, talented, and focused people to make—dare I say it—intelligent decisions to see that those disruptions don't derail the project. It's almost comic to state: "In detail, every part of an airplane is designed deliberately and meticulously for its job" and then imply, by comparisons to biological evolution, that the aircraft as a whole just happens to look and operate the way it does through a random process.

Dan Blodgett
Oxford, Michigan

Congratulations on getting the story of the 747 hump essentially correct. I was with Boeing at the time and had the privilege of negotiating the contracts with a half-dozen of the first 747 purchasers. My sources for the hump story were Tom Spalding, director of contract administration, and the redoubtable Joe Sutter.

I do have one small addition to make to Mr. Sweetman's account. After Boeing extended the cockpit enclosure into the shape of a teardrop, Juan Trippe, the chairman of Pan Am, suggested *further* lengthening the enclosure in order to accommodate a lounge. According to Sutter, Trippe's suggestion had another benefit: the second lengthening reduced the cockpit's drag enough to offset the added weight of the lounge.

I consider the 747 to have been one of the gutsiest projects ever taken on by a U.S. corporation. At the time of its commitment to Pan Am, Boeing didn't even own the land for the facility needed to build the airplanes!

Tim Applegate
La Jolla, California

"How Could You Forget...?"

I must advise you of a gross oversight in "Defining Moments" (Feb./Mar. 2003). Though Roger Bilstein does recall that aerodynamicist Richard Whitcomb verified the area rule theory, he failed to mention the most illustrious applications of the rule: the design and manufacture of the Mach 2 B-58 Hustler, the world's first operational supersonic bomber. Having flown over 1,000 hours in the aircraft, I think that its development ranks very high in the defining moments of aviation history. It was unquestionably the best aircraft I ever flew in the Air Force, and I've flown the F-86, F-84F and -G, F-100, F-102, and B-47 as well. It won the Thompson, Blériot, Mackay, Harmon, Bendix, and Schilling trophies, and it held a total of 19 world records.

Major Robert R. Horness
U.S. Air Force (ret.)
Howard's Grove, Wisconsin

I must take issue with some of the assertions made in your Centennial Edition (Feb./Mar. 2003). No mention is made of the significant aviation developments made by the British. Sir John Alcock and Sir Arthur Whitten-Brown crossed the Atlantic eight years before Lindbergh. Nor is any mention made of Cayley, Pilcher, de Havilland,

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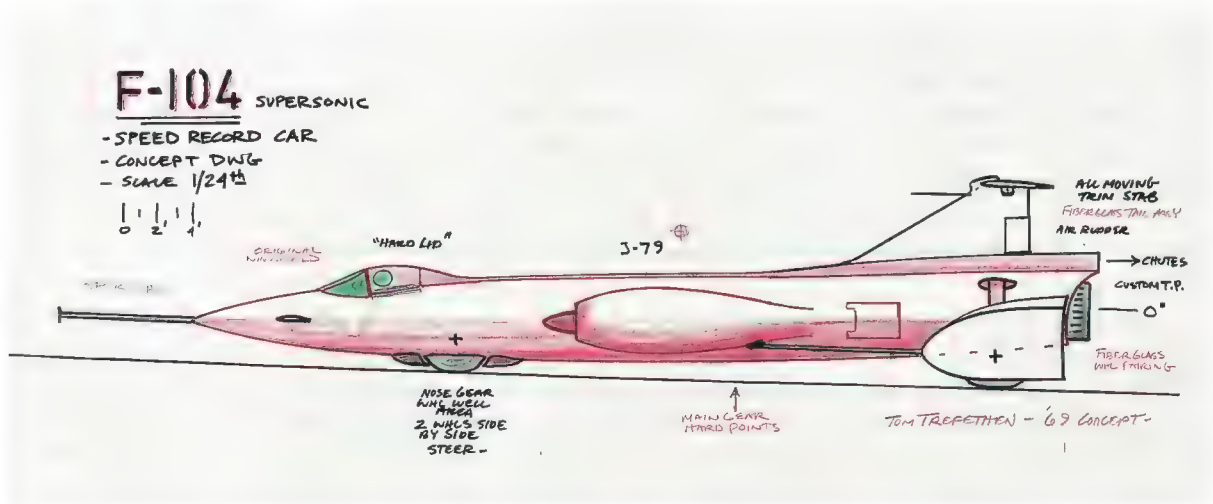
Hawker, Sopwith, A.V. Roe, or the Shorts. Why is it there is no acknowledgment that Britain produced not only the first jet airliner, but the first turboprop (the Viscount), the first practical jet bomber (the Canberra), and the Harrier jump jet? Nor no mention made of the finest heavy bomber of World War II, the Lancaster (which carried twice as many bombs as the Flying Fortress did)?

You also did not acknowledge that Britain was the first to push the world air speed record above 1,000 mph. And why no mention of the world's first automatic landing, or the pioneering ejection seat work done by the British company Martin-Baker? As for the Concorde being a "beautiful blunder," well, it might have done a little better if American politicians and greenies had not tried to stifle it.

Oh, and the Aussies don't get a mention in your issue either. Anyone at *Air & Space* heard of Sir Charles Kingsford-Smith? He was the bloke who first flew the Pacific. Get real, guys. There *is* another world outside of the U.S. of A.

Jeff Watson
Newport Beach, Sydney, Australia



Tom Trefethen's youthful drawings detailed his plan to transform an F-104 into the first car to break Mach 1. Today, another team is turning a -104 into a speed demon.

Shame on you for honoring World War II Luftwaffe airman Eric Hartmann as one of aviation's "greatest pilots." His only accomplishment was downing 352 Allied aircraft and wounding or killing their pilots.

Would you have honored Hartmann if the 352 aircraft he had downed had belonged to the Soviets, and as a result, Nazi banners were now flying over European capitals?

Arnold Goran
Poughkeepsie, New York

One deserving candidate for your "greatest pilots" list is certainly Germany's Hans Rudel. During World War II, he demolished 523 Soviet tanks and 800 other vehicles; he became the first pilot to singlehandedly sink a battleship; and he scored a total of nine air kills. By the end of the war, he had flown a total of 2,530 combat missions. His was an extraordinary aviation career.

Paul Wagner
Tallahassee, Florida

Ah, the Optimism of Youth

In the article about an F-104 Starfighter being reincarnated as a vehicle to break the land speed record ("The Second Time Around," Soundings, Apr./May 2002), Keith Zanghi says: "I'm amazed nobody thought of this before." Well, somebody did, and over 30 years ago. It was Tom Trefethen, my brother.

As a high school senior in 1969, Tom proposed modifying an F-104 fuselage and engine into a "Land Speed Record Car," with the goal of taking a shot at the sound barrier. I have included a sketch he made (opposite).

In 1990, Tom and I signed on to help Craig Breedlove develop a "Spirit of America" supersonic-speed-attempting car. We built the demonstration model, the jet ground-test bell, and the massive S-duct inlets of graphite and epoxy, which fed the car's J-79 engine. We also fabricated the car's nose/pilot capsule.

When I reminded Tom about his high school plans, he said: "...airplane fuselages such as the -104 may not be as strong or stiff as one might think. Traveling through air is quite different from bounding over a rock-hard desert surface at Mach 1." I am sure Zanghi and Ed Shadle are considering this as they adapt the aircraft to land operation.

Tina Trefethen
Lomita, California

Flip-Flopping Over Oshkosh

Why did the map on page 35 of "How to Do Oshkosh" (Apr./May 2003) have north pointing to the bottom, rather than the top? And in an aviation magazine, of all places!

Chuck Manning
via e-mail

The Prolific Mr. Denny

I knew another airplane Reginald Denny promoted ("Launch Count: 15,000 Drones, One Babe," Oldies & Oddities, Apr./May, 2003). It was the Dennyplane, a 72-inch-wingspan, high-wing model airplane powered by a .60-cubic-inch "Dennymite" ignition gas model engine.

Mr. Denny used to have a model-airplane store in Hollywood. My Boy Scout troop made trips to Denny's store, where we were fascinated by all the airplane models hanging from the ceiling.

Lescher Dowling
Sunnyvale, California

Correction

Feb./Mar. 2003 "100 Ways to Celebrate 100 Years of Flight": The Ford Tri-motor shown on page 85 is owned by the Experimental Aircraft Association's Aviation Foundation.

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From the House of Rutan

SCALED COMPOSITES

SpaceShipOne (front) and its booster White Knight (back) were rolled out last April and presented as a turnkey system that will provide relatively inexpensive access to space for aspiring tourists.

Everyone was there for the unveiling of Burt Rutan's SpaceShipOne on April 18 at Mojave Airport in California. Buzz Aldrin, the second man on the moon; first astro-tourist Dennis Tito; round-the-world solo balloonist Steve Fossett; veteran NASA designer Max Faget; and even Shandi Losey, Miss Mojave 2003, maintaining a death grip on her tiara in a 50-mph wind.

We were expecting to see Rutan's contender for the X-Prize, a $10 million award for the first team to launch a three-seat suborbital spacecraft to an altitude of 62 miles, and do it again within two weeks with the same hardware. But Rutan revealed a complete space program, including all the elements that will be needed to carry tourists on the ultimate thrill ride or loft small satellites into orbit. "This isn't arm-waving, it's the real thing," says Jim Benson, whose SpaceDev company is competing to build the components for Rutan's hybrid rocket engine. "It's 90 percent complete and fully funded."

Most of the development work has taken place at a furious pace over the last two years, behind closed doors at Rutan's Scaled Composites factory. "It's been intense—just intense," says one engineer.

The "booster" stage of the two-part vehicle is a gangly, 82-foot-span twin turbojet dubbed the White Knight, with twin T-tails and a gull wing that makes the central crew cabin sit eight feet off the ground. It's designed to carry SpaceShipOne, a 26-foot-long rocket airplane with a teardrop-shaped three-seat body, under its center section.

White Knight drops SpaceShipOne at 50,000 feet. The spacecraft lights its rocket and accelerates vertically to more than 2,000 mph, then coasts to a maximum altitude of 328,000 feet. The descent is unique, a Rutan invention. As the spaceship floats over the top of its trajectory, the rear half of the wing and the twin tails flip up like a peacock's feathers. They stabilize the craft so that its big stumpy wing is facing the slipstream and acts as a huge airbrake. The result is a slow, gradual deceleration, which lowers peak temperatures on reentry. At 80,000 feet, the "feathers" return to standard flight position and the spacecraft glides to a landing on spring-loaded wheels.

Another novel feature is the spacecraft's hybrid rocket engine, so called because it uses a liquid oxidizer—nitrous oxide, commonly known as laughing gas—and a solid rubber-type fuel. Both chemicals are safe to handle, and a hybrid engine, unlike a solid rocket, can be stopped or throttled in flight.

The cabins of the White Knight and SpaceShipOne are identical, with 16 tiny windows. White Knight is not only the carrier vehicle but also a pilot trainer for the spacecraft. With its airbrakes extended, White Knight glides at the same steep angle as SpaceShipOne, so pilots can learn how to guide the smaller vehicle on to the runway.

Next, White Knight, which has already made about 20 flights, will carry the spacecraft on captive flights and will eventually release it, first for glides and later for short-burn rocket flights, before an X-Prize attempt. The goal, says Rutan, "is to find out what it costs to fly three people into space." He expects that any space tourism follow-on vehicle will be larger, carrying six to 10 people.

There are two secrets in the project. One is the identity of the sponsor. The other is the cost, although it's clearly more than the $10 million X-Prize.

—Bill Sweetman

UPDATE

MARK WAGNER/AVIATIONIMAGES.COM

SSTs Take Early Out

Citing a decline in passengers and rising maintenance costs, British Airways and Air France announced in April they will permanently end supersonic transatlantic service ("The Concorde Redemption," Aug./Sept. 2001). Air France was to ground its five Concordes on May 31, while British Airways will continue London-New York service with its seven SSTs through October 31. British entrepreneur Richard Branson wanted to take over British Airways' fleet and put it in service in Virgin livery: "The Concorde has another good 15 years of flying to go," he said. British Airways declined the offer.

Ride 'em, Cowboy!

As pilot in command, how would you like to have your aircraft's tail two feet off the runway, its nose pointed at the sky, your eyes blind to the ground and the horizon, and your hands off the controls? "That was the highlight in my flying career," says German Naval Reserve Commander Rüdiger Knöpfel.

At Naval Air Station Patuxent River in Maryland on April 22, test pilot Knöpfel made the world's first ESTOL landing. ESTOL is "extremely short takeoff and landing," a dramatic maneuver that pitches an aircraft's nose high above the horizon to slow the craft to well below stall speed just prior to touchdown. The airplane then de-rotates—falls over onto the main gear, then the nose gear—to reduce rollout distance to a few hundred feet. "You just couldn't do this manually," says Marine Corps Major Cody Allee, also an ESTOL test pilot. "The flight control engineers put us in places we've never been. But they've done a nice job."

The engineers' nice job has been installed on the X-31, a proof-of-concept fighter designed around thrust vectoring—redirecting engine exhaust—that completed an advanced air combat maneuvering test program in 1995. The U.S. Navy, the German government, the European Aeronautic Defence and Space Company, and Boeing Aerospace brought the X-31 out of storage in 2000 and updated it with software and a new nose for the ESTOL testing. For the past 50-odd test flights, the team had been building up to the first sea-level landing, and by the end of March had mastered make-believe landings in the airplane at 5,000 feet at 130 mph, down from the X-31's usual landing speed of 200 mph.

But at 5,000 feet, a system can be forgiven. Sea level leaves little room for error. Knöpfel's first approach was at a near-normal 12-degree angle of attack. "Where it gets interesting is past 15 or 16 degrees, when we lose sight of the runway," he says. Engineers have incorporated an automatic wave-off into the system, but there is always a point of no return. "Once de-rotation has started, you have to go through with it," adds Allee.

Sitting back and letting the X-31 fly itself onto the ground in such an unnatural attitude demands a load of faith, which the pilots say they have. The fly-by-wire system relies on unprecedented accuracy of flight and positional data. The X-31 has a flush air data system—a nose-mounted sensor that precisely measures airspeed, angle of attack, altitude, and sideslip. And aircraft position is supplied to within an inch, thanks to a new differential GPS-fed integrity beacon landing system.

The Navy has its eye on ESTOL for carrier operations. Landings at higher angles of attack and the associated reduction in landing speeds could permit carrier-based aircraft to land heavier and thus bring back unused weapons and fuel, which would normally have to be jettisoned prior to approach. Moreover, such landings would reduce loads on arrestor and landing gears. For other aviation fields, benefits may be further off but "I think we'll see applications in unmanned vehicle technology immediately," says Allee.

—Graham Chandler

JAMES DARCY/U.S. NAVY

Heads up! The X-31 may soon be able to stop on a dime and give you nine cents' change—or so hopes the U.S. Navy, with an eye toward carrier operations.

Starry, Starry Night

Astronomy enthusiast Anthony Ayiomamitis documented the solar analemma in "Sunrise Analemma with the Tholos (360–350 B.C.) at Ancient Delphi, Greece" (right) by photographing the sun over the course of 2002 at the same time each day on a single piece of film, a feat of astro-photography accomplished only seven times since the first imaging of the analemma in 1979. "As a result of the earth's tilt about its axis—23.5 degrees—and its elliptical orbit around the sun, the location of the sun is not constant when observed at the same time each day over 12 months," he writes. "This loop will be inclined at different angles depending on one's latitude." The figure-eight shape traced by the changing of the sun's position has been represented on sundials and on older terrestrial globes, where it symbolized the changing seasons.

Reality TV for Extraterrestrials

First came the plaques launched in 1972 and 1973 on the Pioneer 10 and 11 solar system probes and etched with drawings of a nude man and woman, as well as silhouettes of the probes themselves (to show scale). Then came the 1974 Arecibo Interstellar Message, a 1,679-bit electromagnetic message depicting humans and DNA in block shapes. Next, the 1977 Intersellar Records sent on Voyager 1 and 2 contained greetings in 60 Earth languages (including that of humpback whales), plus an hour and a half of great tunes and photos of humans at work and play. The cover contained instructions on how to play them.

Now, a new message for extraterrestrials: A Netherlands company, Pavlov Media, has produced a video mixing real footage with animation. The video is an education program, according to its maker. "It's quite funny in a way, but it's quite philosophical in a way too," says

Thuur Caris, who heads Pavlov Media in Groningen, a college town in the north of the Netherlands. The company, which usually produces corporate films, is looking into two ways to send its message into space: first as a 150-kilowatt coded message beamed out through the 70-meter Evpatoriya radio telescope on the Ukraine's Crimean peninsula, and second as an eight-minute CD attached to the Herschel Space Telescope, which the European Space Agency plans to launch in 2007.

Lest prospective aliens think Earthlings all have the idealized bodies depicted on Pioneer, Pavlov's filmed footage dispels the notion. With a vengeance. "On that [Pioneer] plaque, Mister and Miss Perfect are displayed," says Caris, "and aliens might think we're all barbarians walking around naked." One shot in the Pavlov film, for instance, shows a policeman, an average guy who's quite overweight and certainly not athletic. Call him Homer Simpson-esque.

"This video is for making Martians Earth-wise," says Caris, though reports from Mars probes suggest that the Martian population consists primarily of rocks. But Caris sees the project as teaching humans rather than aliens. Sending messages into space, he says, is less an effort to contact aliens and more a ritualistic gesture for those of us on Earth. "The chances are small that we are really going to contact another species," Caris says. "It's more an importance to address big issues."

—Phil Scott

NORMAN KENT

Hold That Pose!

Arizona Airspeed, a team of skydivers, set a record with a freefall formation of 300 people last December. The National Aeronautic Association deemed the feat one of the Most Memorable Records of 2002. It took 14 aircraft to get the team to 20,000 feet, where, on the third try of the day, the skydivers maneuvered in clusters to link up in a spiral and held formation for seven seconds, long enough for skydivers with video cameras to confirm a complete linkage by all participants. The previous record—282 people—was set in 1999 in Thailand.

UPDATE

Bombers Take Flak

An early April storm in Dallas damaged the Collings Foundation's touring B-17 and B-24 with Texas-size hail ("Bomberville," Feb./Mar. 1998). The foundation reports that while the aircraft were parked at Addison Airport, the fabric-covered control surfaces were shredded and some sheet metal and paint on the wings were damaged as well. The Lone Star Flight Museum in Galveston and the Commemorative Air Force's Gulf Coast Wing in Houston lent the foundation ailerons and elevators, and the aircraft continued their national tour. The foundation has launched a fundraising campaign to defray cost increases in maintenance, insurance, and fuel. Visit the Web site, *www.collingsfoundation.org,* or call the foundation (in Massachusetts) at (978) 562-9182.

Gambling on Las Vegas

"The city of Las Vegas is sitting on the largest opportunity in the sport and aviation entertainment industry today," says Bob Avery. The former F-15 pilot, who flies MD-11s for Federal Express, plans to transform Unlimited air racing from a yearly cult event at Reno, Nevada, to a NASCAR-like Winston Cup series of big events backed by big money based in the capital of excess.

In November 2002, Avery's vision came one step closer to reality when Boyd Gaming, a publicly traded owner and operator of 12 casinos, sponsored Avery's first "Las Vegas-style Unlimited Air Racing" at Nellis Air Force Base's Aviation Nation airshow. "At Reno the course is eight miles long, and you can hardly even see the planes half the time," says Avery. "We had ours on a four-mile oval track, and they came down the runway centerline 10 feet apart and 20 feet over the pavement. Man, was it exciting!" The event drew 500,000 spectators and pumped millions into the city's coffers. Boyd Gaming recently announced it will sponsor another two days of racing this November 15 and 16.

There's only one problem with Avery's Las Vegas-style racing. "They aren't racing airplanes," says Michael Houghton, president of the Reno Air Race Association. "It's an airshow act. We've been doing the same thing at Oshkosh for years." Indeed, Avery's 2002 "race" at Nellis was actually an untimed four-airplane demonstration without a purse, one small part of the Aviation Nation airshow that Avery organized.

"I don't know how marketable Unlimited air racing will ever be to sponsors," says racer Matt Jackson, who flew in Las Vegas in 2002. "You have to work all year long to get your plane up for 10 days at Reno, and even three events a year would require a full-time effort. I don't want to bring my million-dollar plane to an airshow—I want to race."

Avery deflects the criticism: "We think this is the hottest opportunity in sports marketing, and a lot of things can happen in Las Vegas that can't happen where they are now. You watch: By 2006 we'll have real air racing in Vegas."

—Carl Hoffman

We found our best watch in a history book

In 1923, a small watchmaker in Switzerland designed the first watch to display the day, month, date, and AM/PM. Only 100 of these magnificent timepieces were ever made and this watch was almost lost to history. Today, they are so rare that one original Steinhausen watch can fetch more than $300,000 at auction.

These watches were among the most stylish of the roaring 20's. And yet no one has attempted to remake the Steinhausen of 1923 until now. The watch design that you see here has been painstakingly recreated from the original to please even the most discerning owner. The owner of this classic multifunctional watch is sure to look distinguished and set apart from the crowd. From the sweeping second hand to the roman numerals on the unique ivory-colored face, every detail has been carefully reproduced. This limited edition watch allows you to wear a watch far more exclusive than a new Rolex, Movado, TAG Heuer or Breitling.

This watch has an classic mechanical movement, the kind desired by fine watch collectors. We have updated this movement with automatic power thus the watch never needs batteries and never needs to be wound. The watch comes in a beautiful mahogany toned wood case and comes with both interchangeable black and brown leather bands.

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"This is Your Captain Clicking"

Pop quiz: You're cruising over California's Mojave Desert, minding your own business, when you spot a Beechcraft Duchess buzzing toward you. Make that directly *at* you. Yikes! What do you do?

If you're test pilot Peter Siebold, you don't do anything. You just kick back in the cockpit and enjoy the scenery while your boss, Scaled Composites vice president Doug Shane, clicks a mouse at a computer in a hangar at Mojave Airport, and your remote-controlled Proteus carries you out of harm's way. (For more about Scaled Composites' ambitious line of products, see "From the House of Rutan," p. 10.)

The brief airborne encounter was one of 20 "conflict scenarios" flown last April as part of a NASA program demonstrating collision avoidance technology designed to eventually enable unmanned aerial vehicles to operate with no more restrictions than manned aircraft.

"We hope that within five years, we can have routine access to the national airspace," says Glenn Hamilton, UAV subsystems project manager at the Dryden Flight Research Center at nearby Edwards Air Force Base. "It's a tall order, but I think it's doable."

UAVs have already proved themselves in hostile environments, such as Bosnia and Afghanistan, but they won't be permitted to fly in civilian airspace until they're as reliably controlled as manned aerial vehicles. They will have to carry a DSA—detect, see, and avoid—system to prevent midair collisions.

Last year, NASA commissioned a series of DSA test flights in Las Cruces, New Mexico, featuring the insect-like Proteus. Created by aerospace maverick Burt Rutan, the one-of-a-kind Proteus is a perfect test bed for the program because it was designed to be flown either by a pilot or by remote control.

In Las Cruces, the Proteus tested a Goodrich Skywatch HP Traffic Avoidance System, which identified intruder aircraft by sensing signals emitted by their onboard transponders. NASA wanted to see how the remotely piloted Proteus would fare with threats that weren't equipped with transponders, so for a test at Mojave, an Amphitech OASYS radar system, often used to alert low-flying helicopter pilots to powerlines, was mounted to a bizarre, bright-red tongue protruding from the nose of the airplane.

The Proteus flew 20 scenarios with airplanes ranging from a fabric-covered Stinson Voyager to an F/A-18 jet fighter. Although a pilot took off and landed, during the tests the airplane was controlled by a personal computer on the ground. "I fly the airplane with a mouse," Shane says.

As expected, the radar's range was significantly smaller than the Skywatch unit's and barely sufficient to allow time for collision-avoidance maneuvers. There were also some glitches in the way flight information was displayed on the computer screen. Still, the technology showed plenty of potential. "In some cases," Siebold says, "the sensors were more effective than the pilots in the air."

Could we one day see UAVs hauling cargo—human and otherwise—as reliably as airliners? Hamilton thinks so. But Dryden test pilot Jim Smolka, who flew a Beechcraft King Air during the program, has his doubts.

"You're not going to see me on a UAV passenger airplane," he says. "I want to know that somebody's going to pucker up before I die."

—Preston Lerner

TONY LANDIS/NASA

Road Trip

The pointy end of an SR-71B two-seat trainer heads for the Kalamazoo Air Zoo museum in Michigan. Lockheed built only two Blackbird trainers; "Article 2007," so named by the Central Intelligence Agency, first flew in 1965. (Article 2008, the second trainer, had a double generator failure and crashed in 1968; both crew members survived.) The surviving B model, with its bug-eyed elevated aft cockpit, was transferred to NASA's Dryden Flight Research Center in California, where it made 93 research flights throughout the 1990s. Another five trailers were required to get the rest of the Blackbird on the road last March.

Wright State Stuff

The third annual International Symposium for Aviation Photography drew 70 enthusiasts to Wright State University in Dayton, Ohio, last February for presentations by top photographers and field trips to landmarks like the U.S. Air Force Museum, Aviation Hall of Fame, Carillon Historical Park, and the Wright State University Special Collections and Archives. The three-day meeting included a few minutes for a group portrait in the WSU Paul Laurence Dunbar Library, under a full-scale replica of the 1903 Wright *Flyer*.

JOE OLIVA/JETPIX

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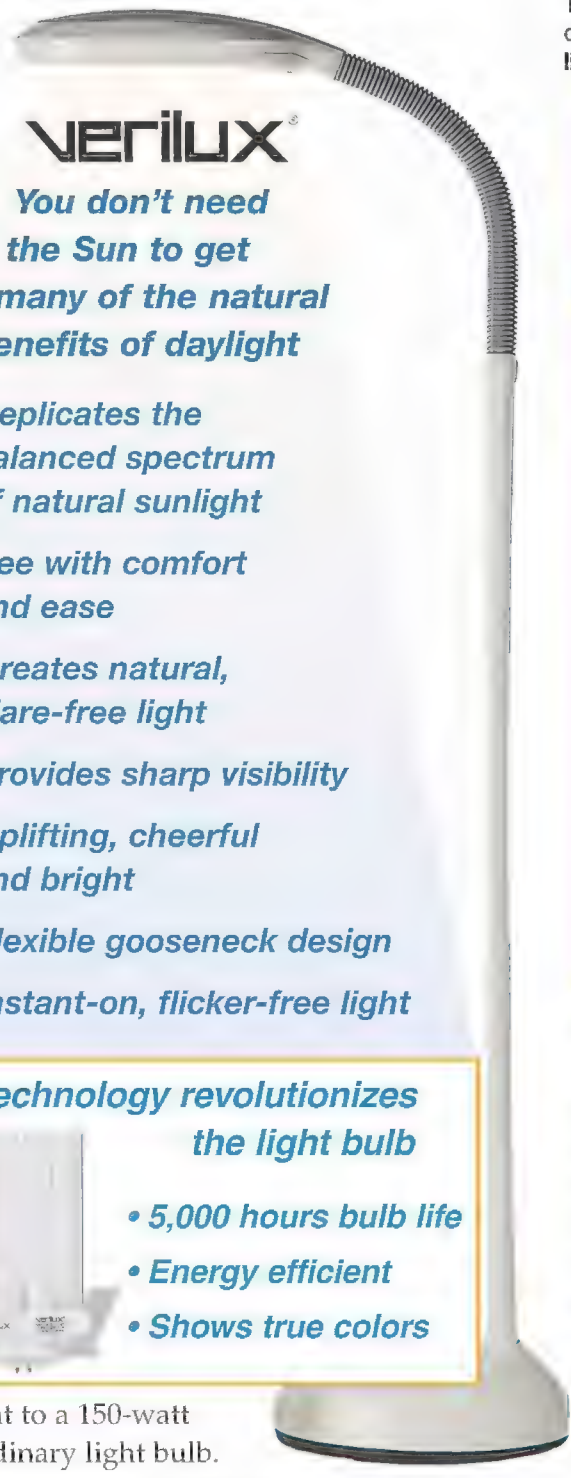

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Obscure Genius

The III f is one of four NASM Horten gliders restored at Berlin's Deutsches Technikmuseum. Below: The II L's beautifully crafted ribs.

Simplicity. In aeronautics, the concept has no more dramatic expression than the flying wing, an aircraft that spares no surface area for anything other than the production of lift. The tantalizing benefits in drag reduction, range, and interior volume have seduced many designers, including two iconoclastic brothers from Bonn, Germany, whose designs would find their way into the stable of advanced German aircraft promised, but never produced, at the close of World War II.

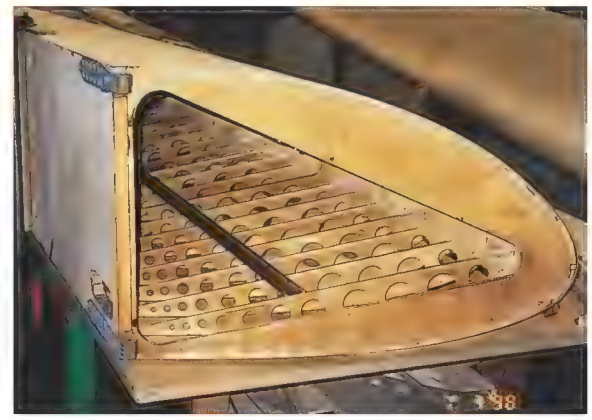
Reimar and Walter Horten weren't yet teenagers when they began experimenting with tail-less glider models. By the mid-1930s, when they were still in their early 20s, both brothers were experienced glider pilots flying their own prototypes in Germany's national competitions. They flew their first motorized design, the Ho V b, in 1938, two years before Jack Northrop, the United States' primary flying wing experimenter, flew his twin-engine N-1M.

Despite the Horten brothers' demonstrated talent, they labored mostly unnoticed. "The brothers built almost 70 aircraft over the course of their lives," says Russell Lee, curator of the National Air and Space Museum's collection of four Horten sailplanes. "But they never really hit a home run in terms of building a widely successful aircraft."

The Hortens—Reimar, the engineer and aerodynamicist, and Walter, the more experienced pilot—were tenacious in their quest to perfect the handling qualities of their aircraft. One of their primary concerns was adverse yaw, which causes an aircraft's nose to stray during a turn. The tendency is easily corrected in a conventional aircraft by applying the rudder—a vertical control surface absent on the pure flying wings the Hortens designed.

The Hortens spent decades perfecting airfoils that demonstrated a bell-shaped lift curve—a distribution of lift that helps to counter adverse yaw, but at a penalty of increased drag. Nevertheless, the Horten wings proved that the brothers' concepts were worthy of further exploration, says Lee.

The brothers continued to experiment with sailplanes throughout World War II, and a handful of their gliders were captured, among hundreds of German aircraft brought to the United States and England for evaluation. Also captured was a prototype of the futuristic Gotha 229, a turbojet-powered flying wing fighter based on a Reimar Horten design that was test flown before the war ended; it is now part of the Museum's collection of jet-powered aircraft.



BELOW: NASM (SI NEG. #94-10736) / JAN SCOTT

Because of his stubborn independence—and the simple fact that his passion had always centered on building the perfect competition sailplane, and not on military aircraft—Reimar was never fully embraced by the German aeronautical community. Even after the war, he failed to find a home for his ideas, not even with Northrop. That company's engineers studied captured Horten gliders for two years, but expressed no further interest in them—a fact underscored by the dismissive note Northrop or a representative scrawled on a postcard Reimar Horten had sent

The Horten VI V1 before a test flight at Göttingen, Germany, in 1945.

ERIC LONG

The Countdown Continues

With the December 15 opening of the National Air and Space Museum's Steven F. Udvar-Hazy Center just six months away, Museum staff have begun moving the first of the dozens of airplanes that will be displayed in the 10-story hangar. One of the oldest airplanes that will be exhibited is the Martin J.V. K-III Kitten (right), a high-altitude fighter designed by J.V. Martin in 1917. During test flying, the open-cockpit biplane managed only a few short hops, but the K-III featured retractable landing gear and an electrical system to warm the pilot's flightsuit.

NASM (SI NEG. #9A-00775)

The Martin K-III never entered service, and its designer donated it to the Smithsonian Institution in 1924.

him in hopes of landing a job. Northrop's first two flying wing bomber designs, the XB-35 and XB-49, drew nothing from the Horten brothers' work.

"Northrop was following a very different philosophy on flying wing designs," Lee says. "I'm convinced that he [Jack Northrop] was in way over his head with flying wings. What he was doing wasn't nearly as advanced as the Hortens' work. There was no evidence at all that he understood the importance of the bell distribution."

After the war, Walter stayed in Germany, while Reimar Horten settled in Argentina and continued building gliders until his death in 1993.

Like their designers, the gliders faded into obscurity. The Air Force gave four crated and battered examples of Reimar and Walter's gliders—a Horten II L, III f, III h, and VI V2—to the Smithsonian Institution in 1952. After languishing for more than 40 years, the Museum's collection of Horten gliders was shipped in 1994 to the Deutsches Technikmuseum in Berlin, which agreed to restore them in exchange for the permanent transfer of the II L. Great benefits came from restoring the gliders in their home country—resources became available that might not have been as readily available to NASM technicians.

"During the restoration of the Horten aircraft, the Deutsches Technikmuseum was able to rely on a great number of spare parts from the heritage of a former Horten employee," says Holger Steinle, who is overseeing the project. Assistance came from leading Horten archivist Edward Uden, who had interviewed Reimar extensively before his death. During the restoration process, Technikmuseum restorers also produced detailed engineering drawings of the airplanes and their subsystems; the careful renderings will aid further study of the Hortens' designs, Steinle says.

The final restoration, of the VI V2, was completed in June, and the other gliders will be returned next summer, to be displayed in the Museum's Steven F. Udvar-Hazy Center at Dulles airport in northern Virginia—beautiful designs providing overdue testament to their creators' genius.

—John Sotham

MUSEUM CALENDAR

June 5 Exploring Space Lecture Series: "Lessons From Mars for Life on Earth." D.E. Brownlee, professor of astronomy at the University of Washington, will explain what Mars can tell us about Earth's past and future, and how a comparison of Earth and Mars demonstrates why Earth has been more successful in sustaining life. Tickets are required and may be obtained by calling (800) 529-2440 or visiting *www.tickets.com*. Einstein Planetarium, 7:30 p.m.

June 6 National Air and Space Society Lecture: "Flight Test, X-15 to the Space Shuttle." Major General Joe Henry Engle, U.S. Air Force (ret.), will discuss his career test flying air- and spacecraft. Engle has logged more than 12,400 hours of flight time during his 25-year career and spent 225 hours in space. Tickets ($15 for society members, $20 for non-members) can be purchased by calling (202) 357-3762. Lockheed Martin IMAX Theater, 8 p.m.

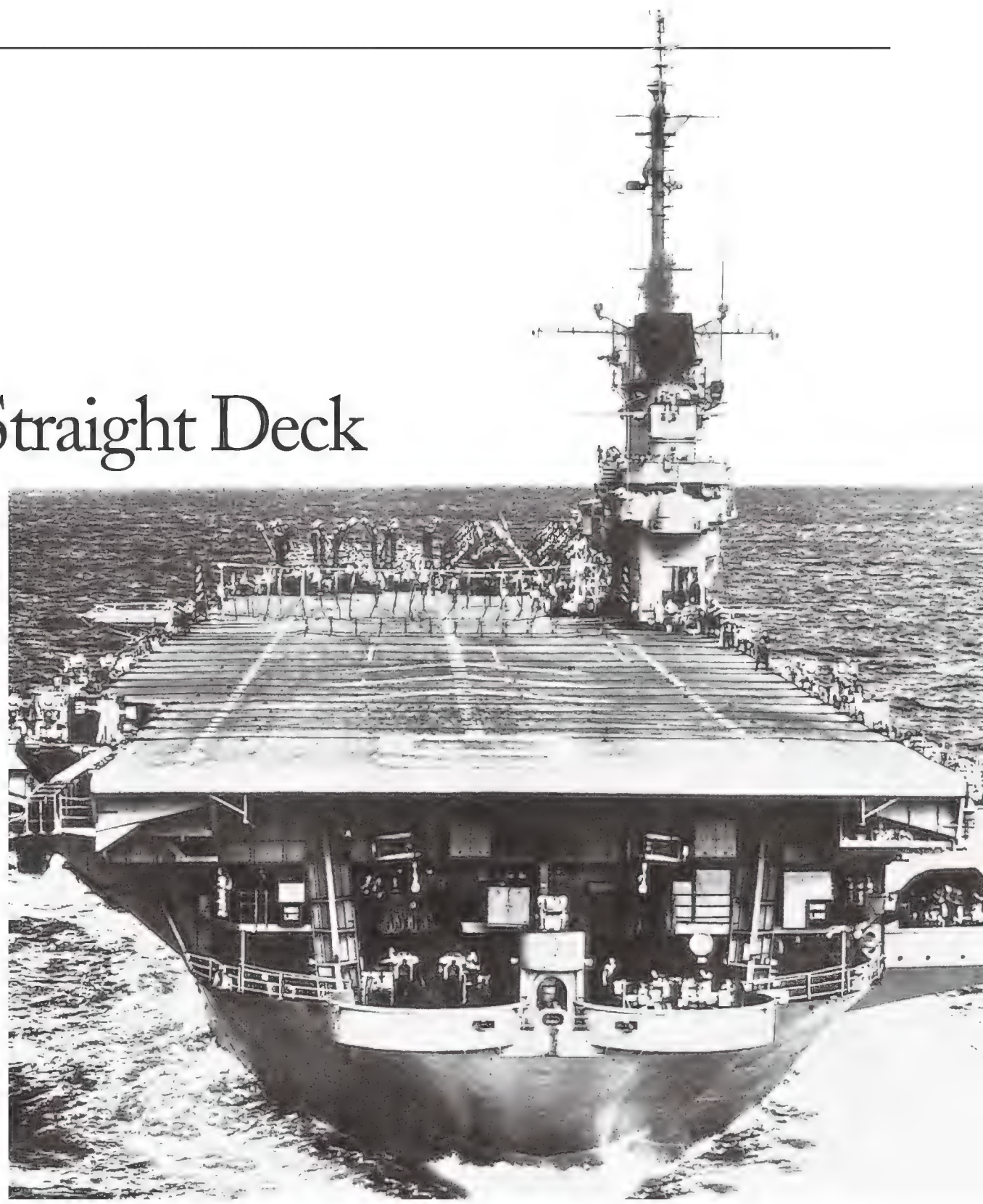
Curator's Choice
Once a week a National Air and Space Museum curator gives a 15-minute talk about an artifact or subject of interest. Meet at the Museum Seal near the Information Desk at noon. June 4, "Spying From Space: The Prehistory of the TIROS Weather Satellite"; June 11, "Space Shuttle *Columbia*: Its History and Demise"; June 18, "Curtiss R3C-1/R3C-2 Racers"; June 25, "Messenger Mission to Mercury."

Lockheed Martin IMAX Theater
Experience the thrill of large-format films projected onto a screen seven stories wide and five stories high. For more information, call (202) 357-1686 or visit *www.nasm.si.edu*.

Dining
The Wright Place Restaurant, which is open from 10 a.m. to 5 p.m., serves breakfast and lunch fare from McDonald's, Boston Market, and Donatos Pizzeria.

Except where noted, no tickets or reservations are required. To find out more, visit www.nasm.edu *or call Smithsonian Information at (202) 357-2700; TTY (202) 357-1729.*

Masters of the Straight Deck



A barrier stretches between the landing area and the aircraft parked forward of it on the USS Essex. *In the foreground, the dreaded ramp, which would eat low-and-slow aircraft for lunch.*

Piece of cake. All I had to do was read the handbook, get on the flight schedule, and have a mechanic help me start the engine so I didn't overtemp it. That's how I learned to fly jets in 1951, at the beginning of the Korean War. I had 340 flight hours, including 90 hours in the Chance Vought F4U Corsair—just enough to be dangerous.

Back then, jets were in short supply throughout the Navy, as were qualified jet pilots. My first jet flight was in a Grumman F9F-3P Panther, and, climbing at 4,000 feet per minute, I was literally in heaven, making steep climbs, fast rolls, and 4-G turns, as well as rolling off on a wing and diving.

Now I had to learn how to get one on board a carrier—a straight-deck carrier, where the airplanes were parked forward of the arresting wires.

There was a certain finality about the straight-deck approach, with its flat pass 80 to 100 feet off the water, to a full cut in power at the ramp, which was at the aft end of the carrier. After the cut, you either caught a wire, went into the barrier, or went over the side. There was no chance for a go-around, as there is now with the angled deck.

The barrier was the key to preventing the landing airplane from plowing into the aircraft parked forward. For propeller aircraft, the barrier consisted of two steel cables, rigged about three feet above the flight deck and forward of the arresting wires. If the airplane didn't catch a wire, the steel cables engaged the prop and the nose, and stopped forward motion. The cost was an engine change. But with a jet, this solution didn't work. Without the big engine and prop to take the hit, the pilot would suffer a quick demise as the barrier cable cut through the cockpit.

The initial solution to stopping a jet was the Davis Barrier. It consisted of straps of nylon woven into webbing stretched across the flight deck about one foot above it, just forward of the last arresting wire. The strap was connected by nylon risers to two steel cables that lay flat on the deck. When the nosewheel strut of the jet hit the strap, the steel cables were snapped off the deck long enough and high enough to engage the main landing gear struts. Obviously, the nosewheel strut was essential to initiate the sequence. What happened if the nosewheel strut collapsed on landing? The steel cable would not snap up to engage the main gear, and the airplane would crash into the aircraft parked forward. Or, if a pilot "dove for the deck," the airplane would land nosewheel first and rotate upward into a flying attitude as the main gear hit. The nosewheel then would fly over the barrier and the airplane would plow into the parked aircraft. The accident rate soared.

A friend of mine, Ralph, a lieutenant junior grade, put on quite a show during his carrier qualifications to demonstrate that the Davis Barrier was not the solution to the problem. He was a multi-engine-aircraft driver, and had transitioned directly out of the four-engine PB4Y-1, a Navy version of the B-24 Liberator bomber, and into the F9F. He had never made a carrier landing in propeller aircraft.

On his first pass, my friend dove for the deck, bounced, and sailed over the top of the barrier. He added full power, and would have gotten away with it except for a Panther parked on the port catapult with its wings folded upward. His aircraft struck the port wing of the parked airplane and ripped loose his starboard main landing gear. Somehow his airplane remained airborne.

The decision was made to attempt to bring the damaged aircraft aboard again. All sorts of equipment used to move, start, or perform maintenance on aircraft on the flight deck was lined up across the flight deck forward of the barrier to stop the jet if it didn't engage a wire or the barrier. Ralph landed again, missed the wires and the barrier, and plowed through the equipment. His other main landing gear and nosewheel were ripped off, and the airplane skidded up the flight deck on its belly. In desperation, my friend cobbed the throttle and miraculously became airborne again. The ship now decided to send him to the shore, something I think they should have done earlier. En route, his escort discovered that the damaged aircraft was streaming fuel. He flamed out and ejected, and was rescued by helicopter. When Ralph returned to the squadron from the hospital, he turned in his wings, saying he had used up all his luck.

A few weeks later my turn came for carrier qualifications. Superbly confident and ridiculously complacent, I repeated my friend's error. I over-rotated, dove for the deck, and landed nosewheel first. The sturdy Panther simply rotated its nose upward as the main gear hit, and I was flying again. Voicing a suitable expletive, I slammed the stick forward trying to engage the barrier. I can still hear the audio and see the video: the *be-bop* of the crash alarm, the startled face of the airplane pusher staring at me as he turned to run for the safety of the catwalk, and the air boss screaming on the bullhorn "Crash! Crash! Clear the flight deck!" For a long moment I could hear and see it all in slow motion before my Panther made an inflight engagement of an arresting wire. Talk about luck. I don't know how far off the deck the airplane was, probably a foot. The wire slammed me down onto the deck. Tires exploded, one wheel shattered, and my back hurt for four months.

Landing on the old straight deck carrier was a hazardous experience, made even more so by the characteristics of the early jets. Their engines didn't spin up rapidly like those of the propeller aircraft, and they had a tendency to sink at approach speeds.

The cardinal sin on a carrier approach was to get "low and slow" at the ramp. In a propeller aircraft, the result was a late wave-off by the landing signal officer. If the approach was very slow, the pilot risked a torque roll as the engine tried to rotate the prop in one direction and the airplane tried to roll in the opposite direction. The engine generally won, and the airplane would roll inverted and crash into the sea.

When a jet got low and slow, the response of the engine was so slow that it could not stop the airplane's sink rate, and the craft settled into the ramp with disastrous results. The outcome was irreverently known as "landing in the spud locker"—the potato storage bin beneath the ramp. It was alleged that one pilot actually flew into the spud locker and survived: The cockpit separated from the airplane and launched itself out of the fireball, through the open double hatch, and onto the hangar deck, where the pilot calmly got out and walked away.

When a jet got low and slow, the response of the engine was so slow that it could not stop the airplane's sink rate, and the craft settled into the ramp with disastrous results. The outcome was irreverently known as "landing in the spud locker"—the potato storage bin beneath the ramp.

The Navy finally did something about the Davis Barrier. Someone invented the barricade that the *Philippine Sea* got before we deployed to Korea. The barricade became the standard for stopping jets, and is still used on today's carriers.

The barricade consisted of two sets of nylon webbing across the flight deck, one 11 to 14 feet high and the other lying on the deck. They were interconnected by nylon risers spaced about two feet apart. The airplane either flew or rolled into the barricade, which wrapped itself about the airplane like a cocoon and dragged it to a stop.

But the use of the barricade did not make low and slow risk-free. Pilots still had to deal with the straight deck and the flat pass to a full cut in power. It was still easy to get low and slow and settle at the ramp. An F9F got a late wave-off for being low and slow; as the pilot turned to avoid the barricade, his tailhook engaged some of the nylon straps. The straps parted, but the partial engagement made a slow aircraft even slower. The aircraft was too cocked up to accelerate without dropping the nose; when the pilot dropped the nose, the aircraft dove into the sea. The airplane broke behind the cockpit, and the pilot never surfaced. In today's jets with modern ejection seats, the pilot could have punched out just before he hit the water and survived. In 1951 the ejection seat was basically manual. After ejection, the pilot had to unbuckle his seat belt, kick himself out of the seat, and locate and pull the parachute rip cord. Minimum altitude for successful ejection was 1,000 feet.

The days of early jets and old carriers were fraught with hazards—the worst of which was our appalling ignorance. It's a wonder that most of us survived. But we did, and we got smarter, and, in the end, we had a lot of fun too.

—*Paul Corrigan*

U.S. NAVY (2)

A barricade brings an errant F2H-3 Banshee to a halt aboard the USS Essex *in the late 1950s.*

Tandem Jump


DAVID CLARK

Chuck Lowery, crouched on the bucket seat beside me, reached up and scratched his head, forgetting to remove his helmet. "I've got it all figured out," he said. "It's 1,200 feet to the ground, and by using the formula $S = 1/2gt^2$, it takes a little over eight seconds to hit the ground if your chute doesn't open."

"Shut up, professor," I said.

It was August 1946, and we were over Frankfurt, Germany, in a C-47, preparing to make our first jump as privates in the 82nd Airborne Division. I looked around the inside of the transport. It vibrated so viciously that everything in it appeared a little filmy, except the open door near the tail. It was a big pale blue hole in the side of the fuselage, and the wind from the propeller blast slammed past it, making a hungry sucking noise.

I hoped that when I got to the door it would suck me out so I wouldn't have time to argue with myself. The fellows across the aisle seemed to be thinking along the same lines. They peered fearfully from under the ledges of their helmets, doing things with their chins. Fear either pulls a man's chin in against his neck, sticks it way out, or wiggles it. I reached up and felt mine, and it was pulled in tight against my neck. When I let it out, it wiggled.

"Your chin," Chuck said.

"I know."

"But you ought to see the way—"

"I know." I pulled it in against my neck, and Chuck soon lost interest in it. After all, he had one of his own.

Now the airplane was circling the drop zone, and the jumpmaster screamed us to our feet. He was a lumpy little sergeant with cauliflower ears and two slick brown scars where his eyebrows should have been. He stomped up and down the aisle, slapping us on our backpacks and checking equipment. Then he took his position by the open door and yelled for us to hook up our static lines: "First stick, get ready! Stand up and hook up!"

The noise in the fuselage was a heavy shivering fluid, pushing into my ears and against my chest and the backs of my knees. Twelve hundred feet below—rather, eight seconds below—the trees waited.

Then we were shuffling toward the hole. I practically rode Chuck's chute as I pushed him ahead of me in my haste to get to that door and clear of the airplane. The men ahead of us were spilling out of the plane swiftly and precisely. The static lines were curved from the anchor cable to the edge of the door, and the propeller blast pasted the lines against the outside of the C-47 after each jumper broke free, so they weren't in the way of the next jumpers. I felt numb as I stumbled along, and the noise grew worse and worse until finally I was a part of it, spinning and somersaulting, a roaring speck of noise in a pale blue sea of air. I caught glimpses of the trees and the thin beige roads growing rapidly as they lunged toward me.

I looked up, waiting to see the silk burst and fill in the air, but there was nothing but the blue sky above. It was in that split second that Chuck's words repeated in my mind: "a little over eight seconds…"

I looked down and there, directly under me, was Chuck's chute, opened like a huge flower. I hit it feet first, flailing at it as I sank, and was enveloped by it.

Dearing, you're dead, I thought. Not with fear, but with a calm acceptance of the inevitable.

There was no chance for me to pull my reserve. The camouflage silk of Chuck's canopy had completely enfolded me, clinging to my body. My own chute had been pulled from its backpack and I was tangled in its lines.

Five seconds.

Four seconds. *Should another man die because of me?*

I had to get free of his chute and fall alone. I fought and flailed and clawed to get to the edge of his canopy. I worked wildly, like a man with lungs bursting, trying to reach the surface of the water from hundreds of feet down. After an eternity I reached the edge and looked down on the earth spiraling toward me at terrific speed. Chuck's suspension lines curved downward and then back up to his body, visible only from the waist down. I grasped his lines with my hands, parted them, and fell headlong through them.

Three seconds. Tremendous pressure stabbed at my shoulders and legs. The unseen hand of momentum almost forced me through my harness as my chute hooked on Chuck's and opened. Tears of joy coursed down my face as I looked up and saw the two chutes hooked together, both open. They both collapsed twice and then blossomed again just before we hit the ground. Before I was clobbered into unconsciousness, I laughed at the punchline that had been drilled into us: "It don't mean a thing if you don't pull that string."

Thirty minutes later, Chuck and I had to jump again. The jumpmaster reasoned that if we didn't go back up right away, we'd refuse to tomorrow.

—James E. Dearing

"Think back to the days of Lindbergh. That was true courage..."

PHOTO: CAROLYN RUSSO

" Before the War, we would just go flying. No chute, no goggles, you just put a jacket on and went. Today, I so admire the people who fly and explore space, and you can see it all here at this wonderful Museum! "

—LIEUTENANT COLONEL, WILLIAM KONZE, US ARMY (RET.)

In front of the "Spirit of St. Louis." In 1927, with Charles Lindbergh piloting, the Ryan monoplane made the first solo, nonstop flight across the Atlantic Ocean. A gift of Lindbergh to the Museum, it's one of the most historically significant aircraft in the Smithsonian collection.

At age 19, Bill Konze flew in open cockpit single winged planes out of a tiny airport in Morristown, New Jersey with a pilot friend. He spent a long and distinguished career as an officer and civilian with the US Army, beginning as a "ground pounder/gravel agitator" (infantry) in WWII. But he never got over the thrill of being up in the air and his admiration for the pioneers of flight.

Recently, Bill Konze established a charitable gift annuity to benefit the National Air and Space Museum, and he is a proud member of the *Smithsonian Legacy Society*.

Find out how you can include the National Air and Space Museum in your estate plans. Fill out and return the reply form below, or call 202-633-2602. You may also e-mail uniong@nasm.si.edu. Salute the courage of everyone in air and space!

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A&S 07-03

Matt Jackson is not an office guy. Wearing a T-shirt and jeans, the burly 44-year-old reports to work each morning at Los Angeles County's Van Nuys Airport, a busy airfield where business jets take off from an 8,000-foot runway surrounded by strip malls and 1950s stucco houses. At Van Nuys, Jackson operates a shop that specializes in restoring "old, junk airplanes," as he puts it. And as much as he loves refurbishing aircraft, the ultimate reward for Jackson is that he gets to fly them afterward.

"I test fly airplanes every day," says the pilot, who must make sure that the airplanes leaving his shop are safe to operate. Jackson also tests aircraft that have never been in his shop. He is one of a handful of pilots in the United States whom other pilots trust with their airplanes and ultimately with their lives. When an airplane has sat for a decade

Would you trust your million-dollar Mustang to this man? Matt Jackson has made a career out of breaking in restored P-51s like American Beauty.

STICKS FOR HIRE

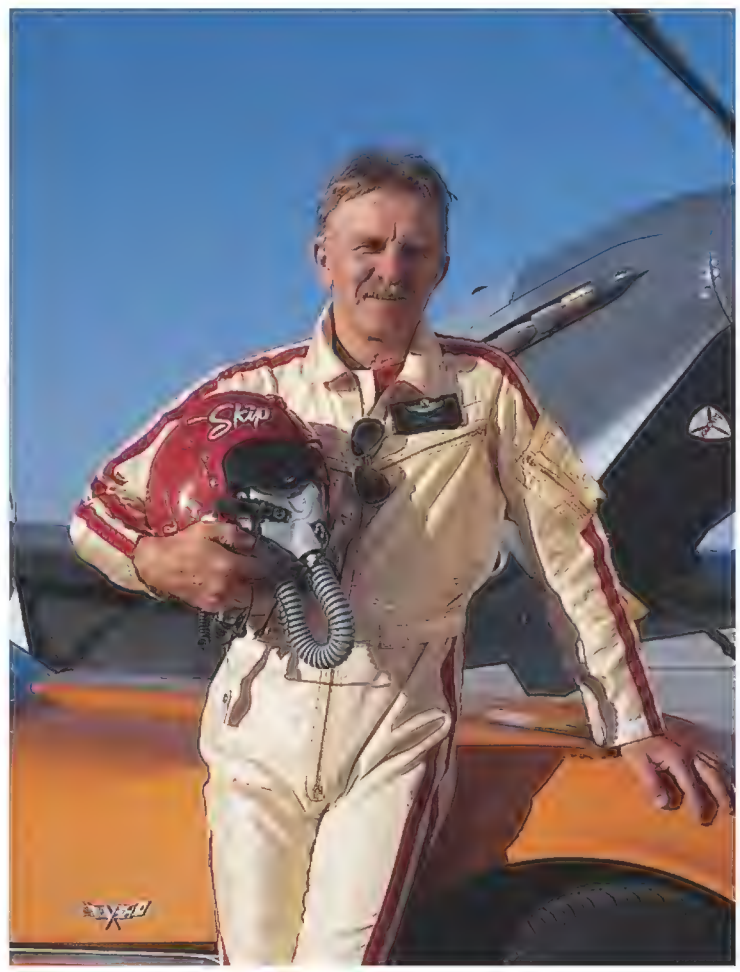
The elite few who check fly restored, vintage aircraft. by Mark Huber

CHAD SLATTERY

and needs to be moved, or a one-of-a-kind antique has undergone an extensive restoration, or you need a hot stick to race your highly modified warbird at the National Air Races in Reno, Nevada, these are the pilots you call.

They come from a variety of backgrounds; they are engineers, pilot-mechanics, airline pilots. In an age of glass cockpits and computerized flight management systems, these pilots do it the old-fashioned way: stick-and-rudder flying mated to decades of experience with old aircraft systems.

John Mohr's experience began with his family business. He grew up on Crane Lake, in Minnesota's Boundary Waters, where he helped maintain airplanes at the seaplane base operated by his grandfather and father. There, surrounded by Piper Cubs and Aeronca Champs on floats, he built his own kit helicopter, a Rotorway Scorpion, at age 17. At 49, he has logged more than 30,000 hours of flight time. During the week, he works as a DC-9 captain and flight instructor for a major airline, and on the weekends during airshow season, he flies an aerobatic routine in his Stearman biplane. His test flying work involves 1920s and '30s aircraft, most of them restored for the Golden Wings Museum in Anoka, Minnesota.



DAVID PETERS

Formerly a fighter pilot in Vietnam, Skip Holm is a frequent pilot-for-hire at the National Air Races in Reno, Nevada.

"There's no typical career path for a warbird pilot," says Doug Rozendaal, who became qualified to fly World War II bombers and fighters for the Minnesota Wing of the Commemorative Air Force after logging thousands of hours hauling freight in a Beech 18. Rozendaal flies P-51 Mustangs, Corsairs, PBY Catalinas, and B-25s when he's not running his business, which sells lubricating oil to farmers and truckers. The reputations of pilots who fly piston-powered airplanes are built over the course of years in the close-knit warbird, antique, and air racing communities, and new business originates strictly by word of mouth. "You don't just call someone up and ask to fly their warbird," says Rozendaal.

People who know the community at Van Nuys Airport probably knew Matt Jackson's dad before they knew Matt. The senior Jackson ran Pacific Continental Engines, a well-known business that rebuilt aircraft engines. Matt hung out at the airport, trading odd jobs like washing airplanes and pumping gas for flying lessons. He bought his first airplane when he was 14. By the time he was 18, he'd had a pilot's license for a year and logged 400 hours, much of it moving airplanes for his father's customers. At 19 he flew his first Mustang, ferrying it back to the airport from the Reno Air Races. There have been many Mustangs since.

Jackson and his technicians recently refurbished a civilian transport that had been converted from a Douglas A-26 Invader.

CAROLINE SHEEN

It takes more than experience, however, to hop in somebody else's treasure and make sure it's put together right. It takes authorization from the Federal Aviation Administration. The FAA requires pilots to obtain a letter of authorization (LOA) for a particular airplane—a Lockheed P-38 Lightning, say—by passing a flying proficiency test, stipulated by sections of the Code of Federal Regulations governing pilots and aircraft operation. Since most aircraft dating back to World War II and earlier seat only one—the pilot—the FAA or an FAA-designated examiner observes the check flight from the ground. Jackson, John Mohr, and Doug Rozendaal are among only a dozen or so pilots with unlimited letters of authorization for piston-powered airplanes: They are authorized by the FAA to fly all piston-powered airplanes. (To receive such an unlimited LOA, a pilot must have at least three individual prop-airplane LOAs.) These pilots have the authority to sign off on any piston-powered aircraft they have test flown, clearing its return to service. (Before even a test pilot can go up in a recently restored airplane, though, a licensed airframe-and-powerplant mechanic must first inspect it for airworthiness.)

The "unlimited" authorization also increases the pilots' earning power. Jackson's test flying brings in $50,000 a year. His fee starts at $500 a day plus expenses and goes up based

on the degree of risk. "I've got five children, and a wife, and a dog, a couple goldfish," he says. "And I have six or seven people that work for me that rely directly on the ability of me to be there every day to make their living. I have to consider all that. So the first thing I do is go and inspect the airplane. And if the airplane meets my requirements in quality in the restoration process, then I will consider doing the test flying."

One of the most expensive jobs Jackson ever took was test flying one man's self-designed homebuilt. Though flight software indicated the never-flown airplane would be stable, Jackson still felt he was taking quite a risk. It turned out, though, the airplane presented no problems, and it "flew just as advertised," says Jackson. For about three hours of flying, which took place over a period of months, Jackson earned $12,000.

In an age of glass cockpits and computerized flight management systems, these pilots do it the old-fashioned way: stick-and-rudder flying.

The economics of restoring vintage airplanes makes owners seek only the most trustworthy test pilots. World War II-era P-51 Mustangs in good condition will fetch upward of $1.5 million, and they are expensive to maintain. Engines can give out after only 500 hours, and rebuilding one can consume more than $150,000. The engines are also fuel-ravenous: A Mustang in high-speed cruise can gulp up to 90 gallons of $3-a-gallon piston avgas per hour. Annual insurance can run to four percent of the aircraft's value, and racing insurance can cost $100,000 for only 10 days of coverage.

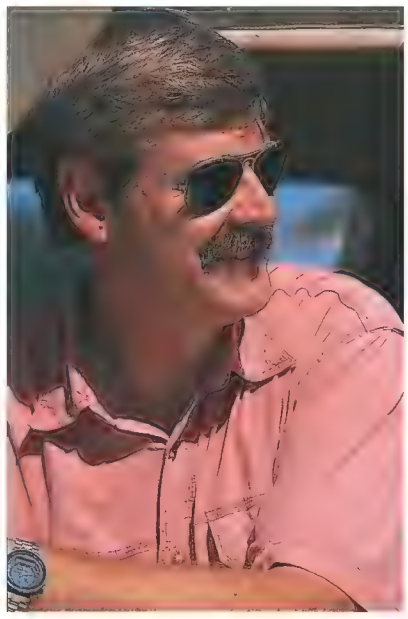
John Mohr has tested about 30 one-of-a-kind aircraft, like a 1938 Cunningham-Hall and a 1936 Stinson Model A Tri-Motor. Though he relishes flying them, he warns that they can be a handful. "You can get yourself in a box in these airplanes if you are not careful," he says. "They don't fly well at all. The rudders are stiff. The elevators are mushy. The ailerons are heavy. The brakes are poor, and the braking systems are all different. You need to be pretty savvy on the brakes." Consequently, Mohr still approaches each test flight carefully, doing extensive ground run-ups and taking other precautions. Nevertheless, "a lot of stuff doesn't work when you first go up and fly it," he says.

While Jackson is restoring an airplane, he simultaneously prepares himself for test flying it. "When I get in an airplane, I know every aspect of that airplane: how it works, what it took to put it together, what it takes to break it," he says. "You're basically becoming part of the airplane as far as systems go, and that's done over a period of months, rather than just hop in and blast off into the sunset."

Holm's fee for checking out airplanes, such as this Yak-3 reproduction, is $600 a day plus expenses.

BELOW: DAVID PETERS

On first flights after restoration or major maintenance, Jackson brings a long sheet of paper for writing down maintenance problems, or squawks; some of the things he typically finds are sticky cockpit canopies, radios that don't work, and inoperative landing-gear lights, problems that are more of a nuisance than cause for alarm. In fact, Jackson says that most of his test flights pass without incident. "The majority of a test pilot's job is not dealing with a problem, it's noting to *see* if there's a problem. The only reason why you want somebody that's qualified there to deal with it is when there is a problem, you want the plane brought back. I mean anybody can jump out of one, and anyone can crash one. So the trick is to find somebody that can deal with an emergency, to bring it back so you can fix it."



ERIK HILDEBRANDT (3)

John Mohr specializes in test flying aircraft from the 1920s and '30s. Last fall he took up a 1929 Kreutzer Air Coach K-5 (right), a six-passenger airliner with a heated cabin.

When a serious problem does arise, however, Jackson says that his response is measured, not heroic. "The flying is calculated because it's the 'You know what's going to happen before it happens' kind of thing," he says. "Really, we're not reinventing the wheel here. The [type of warbirds] that I fly after restoration have thousands and thousands of proven hours in them."

Before he started flying warbirds, Doug Rozendaal logged thousands of hours as a freight pilot.

Vlado Lenoch knows a thing or two about measured responses to inflight emergencies. An aerospace engineer with degrees from Purdue and the Massachusetts Institute of Technology, Lenoch worked for Boeing as a test engineer and later for several major airlines as a pilot. In 1988 he bought a P-51 Mustang, which he raced at Reno. Within the Midwest's Mustang community he soon earned a reputation as a skilled stick, and he occasionally would ferry the pricey warbirds for their owners.

When Mike Vadeboncoeur and his employee David Young needed someone to test fly a Mustang they had spent hundreds of hours restoring, they decided Lenoch was their man. Vadeboncoeur owns Midwest Aero Restorations, based in Danville, Illinois. Since 1999 he and Young had been working on *Cripes A'Mighty*, a P-51D owned by Ken Wagnon of Wichita, Kansas. Wagnon's aim was to restore *Cripes A'Mighty* back to the colors and specifications of the U.S. Army Air Force's World War II 352nd Fighter Group, and he spared no expense. The 12-cylinder Rolls-Royce Merlin engine had been completely rebuilt. New aluminum skins and new side cowling were fabricated. The colors were meticulously researched. At the 352nd's old headquarters in England, the men's room had been painted with the group's original colors, so Vadeboncoeur and Young had a brick liberated from

the wall and shipped Stateside so they could exactly duplicate the blue needed for *Cripes A'Mighty*'s nose.

Finally, in May 2002, *Cripes A'Mighty* was ready for its first flight. Over the course of 45 minutes, Lenoch took the Mustang to 8,000 feet and pushed it to 260 mph ("I didn't want to crack the paint or load up the airplane too much," he says). Aside from a few problems related to trim and engine instrumentation, all was well.

On the second flight, Lenoch took the airplane to 7,000 feet. "Everything checked out fine," he says. "Then I reduced power to come back and land." As he descended through 3,000 feet, Vadeboncoeur, who was watching from the ground, radioed, "Hey, you're streaming fluids." Lenoch radioed back, "Yeah. The oil pressure is at zero."

A piston rod had separated from the top of the piston, and, while still attached to the crankshaft, broke out the side of the engine. "It basically sawed the engine in half," says Vadeboncoeur. Lenoch, who characterized the failure as "almost instantaneous engine destruction," shut down the engine and set up for a dead stick landing. "He pitched up, threw out the gear, dropped the flaps, and made a great landing," says Vadeboncoeur. And saved one very expensive restoration.

A piston rod had separated from the top of the piston and broke out the side of the engine. Says Mike Vadeboncoeur: "It basically sawed the engine in half."

In rebuilt airplanes, engine failure is not uncommon. Last February, Matt Jackson was hired by his friend, Howard

Keck, to test fly a civilian transport that had been converted from a Douglas A-26 Invader. During the three weeks it took to ensure that the airplane was ready to return to service after being refurbished at Jackson's Van Nuys shop, Jackson made five test flights. On the third flight, the transport's right engine failed on takeoff. Jackson wanted to land as soon as possible, but his most immediate concern was clearing the power lines that loomed ahead. After that, he worked to keep the aircraft from crashing into the densely populated area surrounding the airport, then he landed safely. "It was a dangerous situation, but it was still routine for an engine failure," he says.

ERIK HILDEBRANDT (2)

Mohr frequently flies for the Golden Wings Museum in Anoka, Minnesota, which owns this 1938 Cunningham-Hall PT-6F.

During Jackson's final test flight in the transport, which lasted two and a half hours, the airplane performed flawlessly. Afterward, Jackson signed off on the aircraft, authorizing its return to service. Since then, it has logged more than 150 hours as Keck's personal aircraft ("I use it like it's a King Air, but it's a lot more fun to fly," he says).

Keck and Jackson are part of a group of warbird owners and pilots based at Van Nuys. When not flying, they often gather at nearby Millie's Café to talk shop. Test pilot Skip Holm is one of the regulars, and also a perennial rival of Jackson's at the Reno air races ("We're all friends and we're all trying to get one up on each other," confides Jackson).

Unlike Jackson, Holm got into the business of test flying warbirds based on his experience as a pilot for the U.S. Air Force. During the Vietnam war, Holm flew three tours of duty in F-105s and F-4s, and by the end of the war he had become the U.S. fighter pilot with the highest combat time:

John Dilley is another expert in restoring and test flying Mustangs. He fits the profile: A Reno racer with years of warbird experience.

more than 1,000 hours. After Vietnam, Holm joined Lockheed's Skunk Works, where he became a test pilot for the F-117 stealth fighter program. Fellow Skunk Works pilot Bill Park introduced Holm to Mustang enthusiast Dave Zeuschel, and in 1981 Zeuschel asked Holm to fly a P-51, *Jeannie 69*, at the Reno air races.

ERIK HILDEBRANDT

When not test flying aircraft for his clients, Vlado Lenoch likes to wring out his own P-51, Moonbeam McSwine. *"I fly my own airplane a little more aggressively," he says.*

Holm had barely any experience flying World War II aircraft, but he ended up winning his race with an average course speed of 450 mph. The phone hasn't stopped ringing since. Over the last 20 years, Holm has flown a dozen different racers at Reno, including well-known winners like *Dago Red*, *Stiletto*, *Out-of-Bounds*, and *Rare Bear*. Charging $600 a day plus expenses, Holm also test flies 15 to 20 client aircraft a year and has flown for a number of movies, including *The Right Stuff* and *Hot Shots*.

Skip Holm had barely any experience flying World War II aircraft, but he won his race. The phone hasn't stopped ringing since.

Naturally, Holm's friend, Wayne Wainwright, chose him to help test fly his 1945 Russian-built Yak-11. Wainwright had spent 10 years and 14,000 hours restoring and modifying the airplane. He had stuffed a Pratt & Whitney R-2000 radial engine (taken from an old DC-4 airliner) into the nose. He had reworked the cowling to improve air flow over the cylinders. He had a craftsman in Texas fashion a new prop spinner, and had almost all of the metal reworked and painted a glossy two-tone gray. When he was through, Wainwright had a 515-mph hot rod that climbed at 5,000 feet per minute through 16,000 feet, a rate of climb better than that of most civilian jets. But he hadn't flown it, or much of anything else, in two years. Being a cautious man, he wanted an experienced test pilot like Holm to accompany him in the rear cockpit while he reacclimated himself to his airplane.

An airframe-and-powerplant mechanic, Jackson thinks the best test pilots are mechanically inclined. "When something isn't working correctly," he says, "they know why immediately."

On an overcast afternoon last October, Holm drove his bronze Mercedes through the gates of the airport in Camarillo, California, and past a duo of Lockheed Constellations. At Wainwright's hangar, Holm and Wainwright pored over the Yak like two high schoolers who had just been given the keys to their first car. Holm nonchalantly cross-examined Wainwright about modifications made to the Yak, and Wainwright beamed while he explained the details. As the two men climbed into the cockpit, Wainwright shouted back over his shoulder, "Don't assume anything."

The Yak snapped off the runway, went wide in the pattern to avoid much slower traffic, and made three good landings. Afterward, Wainwright presented his logbook to Holm for endorsement, smiled, and asked, "What are you doing Saturday?"


CHAD SLATTERY

FAIRFORD SKETCHBOOK

THE ROYAL INTERNATIONAL AIR TATTOO IS A FLOWERY, BRITISH COUNTRY AFFAIR—AND EUROPE'S LARGEST GATHERING OF MILITARY AIRCRAFT.

by Roger A. Mola ➢ *Illustrations by Harry Whitver*

Partly because it has the longest runway in Great Britain, extended by the U.S. Strategic Air Command in 1950 to 10,000 feet, RAF Fairford in Gloucestershire, 80 miles west of London, annually hosts the Royal International Air Tattoo. In the United States, a two-day celebration of aviation with aerobatics, flyovers, and static displays of aircraft is called an "airshow," but "tattoo" means the same thing (and has evolved into "an outdoor military exercise," its current definition, from the 18th century term "tap-toe" or taps shut, a signal calling soldiers or sailors to quarters at night).

Although the Royal Air Force is the largest presence, the Fairford tattoo is indisputably international: Last year 300 airplanes from 35 nations formed a two-mile static display, and national demonstration teams included La Patrouille de France flying eight Dassault/Dornier Alpha Jets, Spain's Patrulla Acrobatica Aguila with seven CASA C-101EB Aviojets, Patrouille Suisse in six Northrop F-5E Tiger IIs, and the Royal Jordanian Falcons in four Extra EA300s. The Los Halcones team of Chile arrived in an ancient 707 with five crated Extra 300s in the cargo hold.

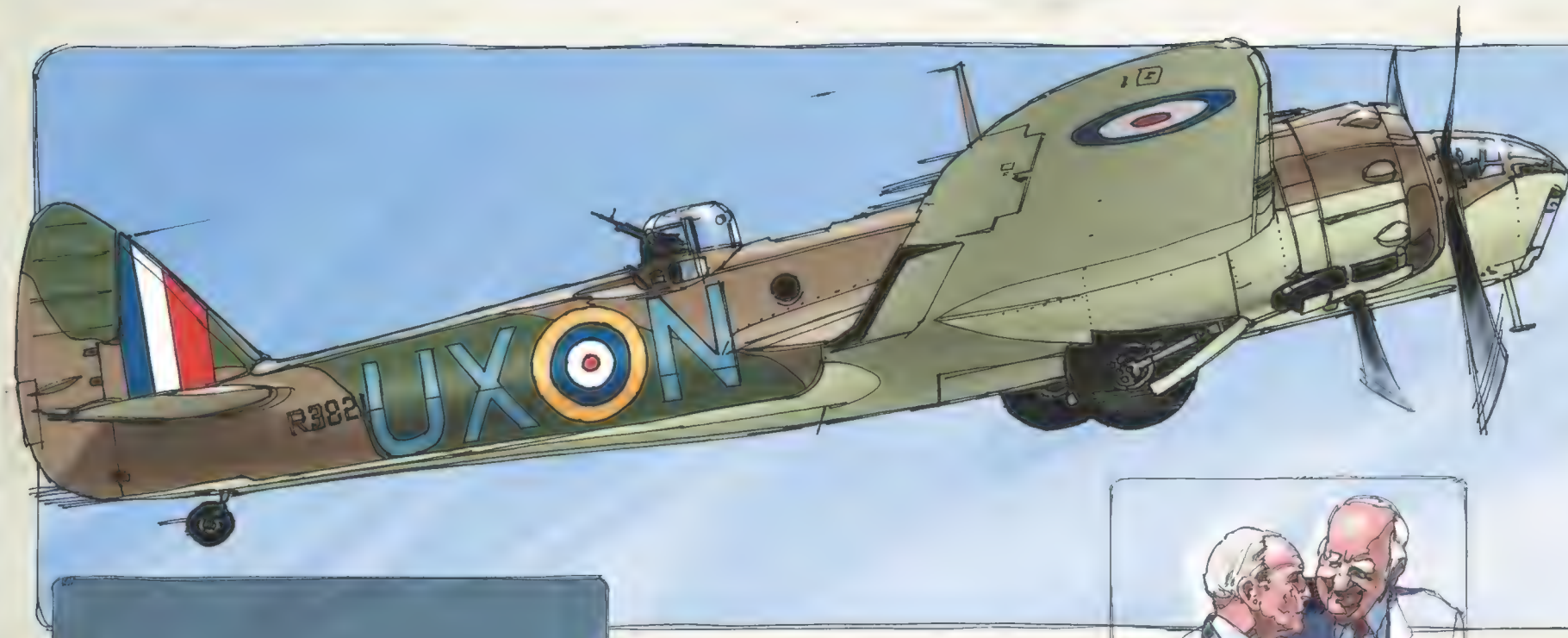
But the event is also unmistakably British. In honor of the Queen's Golden Jubilee, a year-long celebration of Queen Elizabeth II's 1952 accession to the throne, the 2002 tattoo opened with a "flypast" ("flyover" in the United States) spanning five decades, with the British Electric Canberra B2/6, Hawker Hunter F6A, Sepecat Jaguar GR3, Panavia Tornado F3, and a pair of BAe Sea Harrier FA2s. As the British demonstration team, the Red Arrows, flew its routine, the crowd sang along to "Rule Britannia." During previous tattoos, the RAF has flown in a formation spelling "E II R."

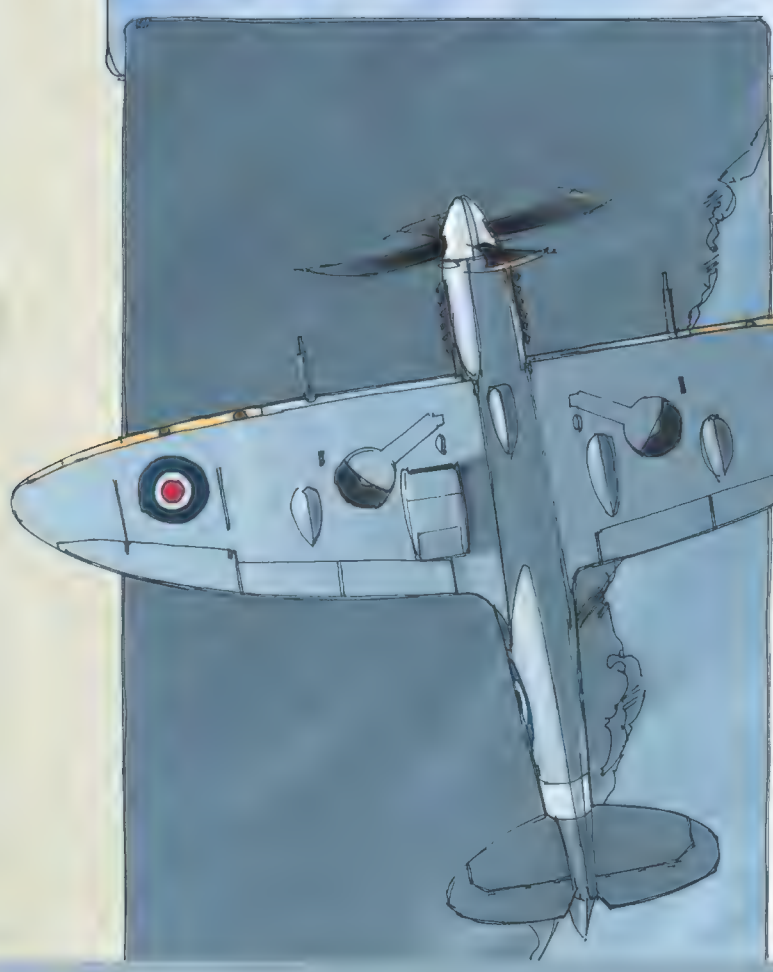
RAF Fairford opened on January 18, 1944, to accommodate the British and U.S. troop carriers and gliders that would be used during the D-Day invasion of Normandy. Today's tattoos reflect that heritage with flights of British and U.S. aircraft that fought in World War II.

The 2003 RIAT will celebrate 100 years of flight on July 19 and 20 with replicas of the 1903 Wright *Flyer* and Blériot XI and such historic aircraft as a Sopwith Camel, Avro 504K, de Havilland Gypsy Moth, and Gloster Meteor, Javelin, and Buccaneer. The organizers fill each day with at least 150 flying displays. For more information, visit *http://www.airtattoo.com*

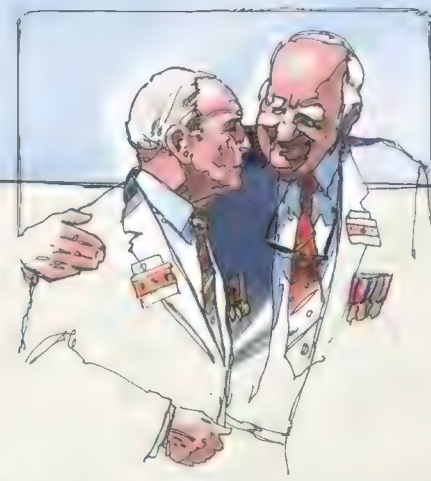
◂ **One of only two Avro Lancaster bombers still flying (the other is in Canada), the Lancaster Mk III, operated by the Battle of Britain Memorial Flight, makes an annual appearance at the tattoo. Wearing the 61 Squadron's markings and a portrait of Mickey Mouse on its nose, the bomber honors *Mickey the Moocher*, a 1943 Lancaster that survived 128 missions.**

▾ **Another regular feature, the Utterly Butterly Barnstormers fly Boeing Stearman A75N-1s for a wingwalking act.**





▲ To mark the 60th anniversary of the U.S. Eighth Air Force's formation, the organizers staged a two-hour Salute to the Bomber Crews. The Aircraft Restoration Company's Bristol Blenheim IVT and Supermarine Spitfires from the Battle of Britain Memorial Flight joined other British and U.S. vintage aircraft performing the salute.



▲ RIAT is a magnet for veterans. Aircrews from both sides of the Atlantic—and both sides of the Channel—trade stories each year.

▼ U.K. flying committees require maneuvers to be flown 300 feet or more above ground level and aerobatics at 500—higher than at U.S. airshows but low enough for a Panavia Tornado GR4's high-speed pass to prove heart-stopping.

▶ A Royal Navy de Havilland Sea Vixen FAW2 added color to the static displays.

▲ Besides the Roy Kirby Paragon Jazz Band, other roving music ensembles such as Brass with Class entertain the crowds at Fairford. The RAF Central Band belted out its "Fantasia on British Sea Songs."

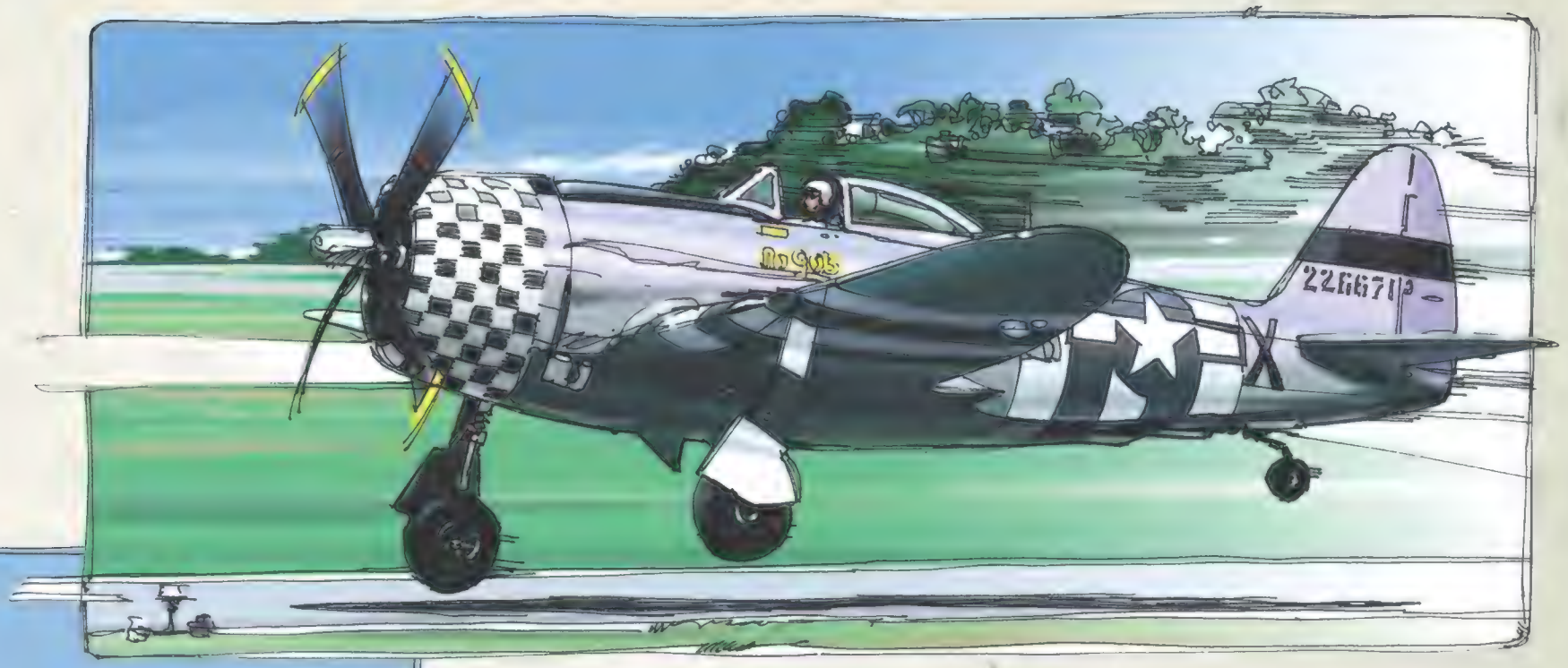
▼ RIAT sells 200,000 general admission tickets. About 6,000 corporate guests pay a bit more to support the Royal Air Force Benevolent Fund. Aerospace companies pay as much as $60,000 to host 50 guests in a chalet with air conditioning, crisp linens, roses, private garden, four-course luncheon, and French wines.

▲ England's contribution to vertical-takeoff-and-landing technology, the British Aerospace Harrier GR7, is always a popular performer at RIAT. At last year's tattoo, seven Harriers, including several Royal Navy Sea Harrier FA2s, made a din at the flightline.

▲ The 42(R) Squadron flew one of its Hawker Siddeley Nimrod MR2s to Fairford from its base at RAF Kinloss in Scotland. The Nimrod is a long-range maritime reconnaissance and anti-submarine aircraft.

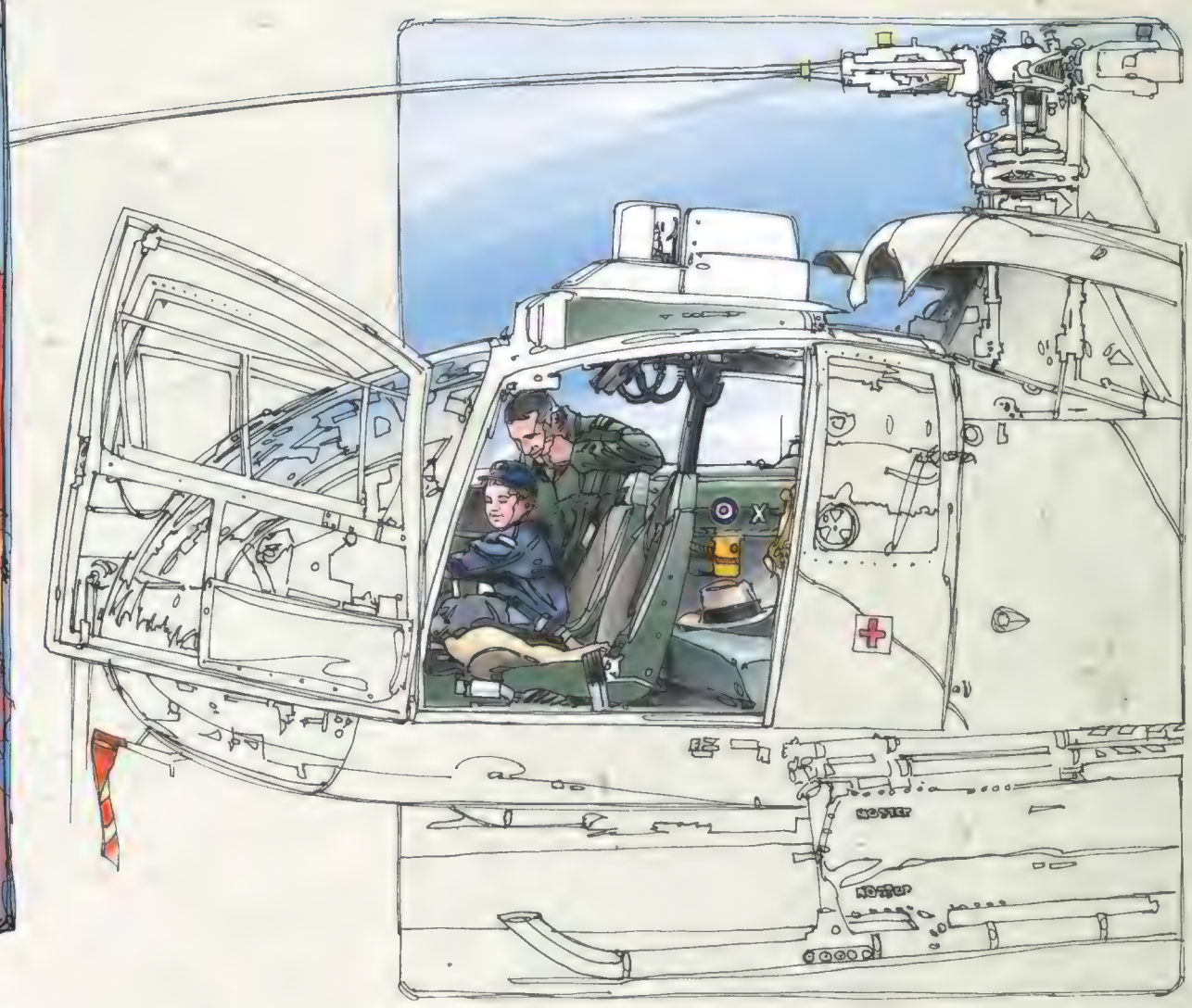
▼ German air force pilots invited the crowds to look under the canopy of their swing-wing, Mach-2-capable Panavia Tornado IDS, jointly built by Germany, Italy, and the United Kingdom.

▶ Pavarotti boomed from loudspeakers as the Italian aerobatic demonstration team, Il Frecce Tricolori, flew its 10 Aermacchi MB339A/PANs in an exuberant routine. The team transport, an Alenia G-222 TCM, had created its own operatic display on opening day. The G-222 pilot made a descent so steep that on landing the nosewheel collapsed, and the aircraft screeched 2,100 feet in fountains of sparks before stopping. The three crewmen were unharmed.



▲ Wearing the checkerboard cowling of the U.S. Army Air Forces' 78th Fighter Group and D-Day invasion stripes, the Fighter Collection's Republic P-47D Thunderbolt paid tribute to the bomber crews that the type had helped protect 60 years ago. The Duxford-based Fighter Collection, a group that restores and operates warbirds for airshows and films, painted its "Jug" to represent *No Guts! No Glory!*—the P-47 flown by squadron commander Ben Mayo. The 78th Fighter Group was also based at Duxford from 1943 to '45.

▼ The U.S. Army has the Golden Knights; the British have the Blue Eagles, who perform not with parachutes but with Army Air Corps Westland Gazelle AH-1 helicopters in an exhibition complete with colored smoke. At the 1993 tattoo, the all-volunteer team, based at Middle Wallop, won the prestigious Wilkinson Sword, awarded for "Best Display by a U.K. Participant."



Admit it.

JOYSTICK AND KEYBOARD HAVE NEVER BEEN ENOUGH. YOUR FANTASIES INCLUDE A YOKE, RUDDER PEDALS, A G-SUIT, AND *LOTS* OF COOL KNOBS AND BUTTONS. YOU WANT TO STRAP INTO AN EJECTION SEAT (NOT YOUR DESK CHAIR), TAP THE ARTIFICIAL HORIZON (JUST TO SEE THAT IT'S NOT STUCK), AND BANK INTO CLOUD-STUDDED TURNS (RATHER THAN THE WALL CALENDAR). YOU'RE A CLOSET SIM GEEK. HERE ARE YOUR HEROES.

HOME-GROWN

Flight attendants! Ejection seats! A Ford Falcon? The world's

GARAGE-KEPT F/A-18

Brian McKenzie remembers the day 13 years ago when he decided to build his own simulator. "I took a trip on a real F-18 sim when I was in the Royal Australian Air Force and it inspired me. Why should pilots have all the fun?" With the help of library books and the Internet—he wasn't allowed to take photographs when in the service—McKenzie was able to build one of his own. It runs on a network of four computers and uses Microsoft's Flight Simulator 2002 and a host of specialized add-on programs.

The faux Hornet's sheet metal-on-wood fuselage is topped with a fiberglass canopy. His ejection seat—an exact replica of a Martin-Baker SJU-9—was fabricated from plywood, and though McKenzie's work is spectacular to look at, it's equally capable of impressing other senses. Two monster subwoofers under the seat generate noise and vibration, and a flight-suit donated by a visiting U.S. Air Force officer completes the illusion; an air bladder under the seat cushion inflates to push the pilot against the straps if he pulls negative Gs.

McKenzie purchased the sim's instruments on eBay—a move that raised suspicion among Australian authorities; his Mullumbimby, New South Wales home was raided by customs officials and police who feared he was importing weapons. After hours of searching and a round of interviews, an inspector called to say, "Great simulator."

members.optusnet.com.au/~brianmac18

COURTESY OF BRIAN MCKENZIE (2)

Brian McKenzie's F/A-18 is no longer considered a threat to Australian national security.

WIDEBODY ON WHEELS

Adelaide's John Dunkley has transformed an Aussie-model Ford Falcon XF chassis into a three-quarter-scale replica of a 747 cockpit. After four years of construction, he's ready to take the next step—mounting it on a hydraulic platform that will simulate pitch, yaw, and roll.

Dunkley has long been fascinated with Boeing jumbo jets—the license plate on his family's car reads "747-400." "Prior to 9/11, I got a ride in the cockpit on every flight I took," he recalls. "I produced a booklet about what I was doing and I'd hand it to the chief purser. My sim was my ticket to the flight deck."

Dunkley admits that his mock 747 isn't quite on par with the real thing, but that doesn't stop him from feeling as if he's really in the jetliner's left seat, flying to real destinations. "Hong Kong Kai Tak Airport is really my favorite," he says. "I like to do a full [Instrument Flight Rules] departure and an instrument approach at night. It's a thrill every time, even though I've done it hundreds of times."

He hopes to have the sim fully operational in a few years, but he knows that projects like this never feel totally completed. "I've got a very understanding wife," he says. "I think she'd rather I was in the sim than down at the pub."
www.senet.com.au/~dunkleyj

The sim will tilt to mimic banks and dives.

COURTESY OF JOHN DUNKLEY

N SIMULATORS

most elaborate home-built simulators. by Matthew Stibbe

BUCKLE'S BEAGLE

If Gene Buckle's simulator looks like an actual F-15C, that's because it is. Buckle spent the last two years adding authentic and replica components to a nose section purchased from an aviation museum. The simulator—he's nicknamed it the Beagle, a derivative of the F-15's official name, Eagle—and the computers that run it fill his Tacoma, Washington garage.

His goal—building an accurate reproduction of the F-15's systems—has led him on a long and pricey quest. Authentic military instruments can run $6,000 each, and cheaper surplus equipment is scarce. The Air Force's demilitarization procedures haven't helped; instruments are often processed beyond recognition or destroyed altogether. "I sometimes get handed a bag of fragments and have to piece them together," Buckle complains.

The software engineer frequently relies on machinists who delight in constructing replicas of two-inch fuel flow gauges, but there's often a lot of begging involved ("I talk to a lot of people to make sure they remember 'that crazy guy who's building an F-15' "). Buckle dismisses the idea that using reproduction pieces diminishes the sim's authenticity. "It's mostly theater," he says. "If I can trick you into thinking it's real, who cares if it's real or not?"
www.f15sim.com

COURTESY OF GENE BUCKLE

Patches and holes punched in the fuselage lead Gene Buckle to believe that his F-15 was used to train ground crews in battle damage repair.

COURTESY OF DAREN KNIGHTSBRIDGE

Daren Knightsbridge and air crews flew the shed "around the world" in 2002 to raise over £5,000 for charity.

COAL BUNKER BOEING

Most south London sheds house lawn mowers or mulch, but inside Daren Knightsbridge's, you'll find a complete 767 flight simulator. Refurbished airliner seats and plastic panels have convincingly transformed the former coal bunker into the flight deck of a jumbo jet. Knightsbridge is proud of his work: "I'm a truck driver, not an engineer," he says. "Everything I've done, I've had to learn how to do it myself."

Each November, a roster of enthusiasts, including the managing director of London's Gatwick Airport and several airline pilots, fly his simulator non-stop for a week to raise money for children's charities. They follow the schedules of British Airways, Virgin, and EasyJet airlines, among others. "We try to plan it as realistically as possible," he says. "British Airways provides the routes and supplies approach plates." Legions of other supporters log on to his Web site to become air traffic controllers or fly along from other computers. (An online group of supervisors makes sure nobody is flying recklessly. See *www.vatsim.net* for more about virtual air traffic control.) Ever dedicated to realism, crew members even eat airline food donated by Knightsbridge's employer, Gate Gourmet, while they fly. *www.world-flight.org*

FLIGHT SIMULATOR TECHNOLOGY

Hardcore hobbyists' simulators rely on elaborate combinations of hardware and software, but three elements—Microsoft's Flight Simulator, the extended/programmable input controller, or EPIC, card, and add-on software designed by Enrico Schiratti—are so ubiquitous that it's hard to imagine the hobby without them.

Flight Simulator is the glue that binds most simulators together; it generates through-the-windscreen views and the flight-dynamics data used to run instruments, replicate an aircraft's flight envelope, and create an external environment. The program is also popular because Microsoft makes a software developers kit available to enthusiasts who want to design airports, cockpit displays, or entirely new aircraft.

While Flight Simulator can replicate views seen from cockpit windows, Enrico Schiratti's software is used by enthusiasts around the world to mediate internal displays: instruments and other flight management and electronic information systems. Schiratti is considered the guru of the flight sim community; he wrote software for F/A-18 cockpit displays in the film *Behind Enemy Lines* and managed to incorporate Boeing's enhanced ground proximity warning system into simulators before Boeing could equip its own simulators with the system.

EPIC cards serve as the interface between Microsoft's or Schiratti's software and hardware such as LED displays, joysticks, toggle switches, dials, and lights. Without them, homebuilt simulators wouldn't be as realistic.

For very complex simulators, as many as six computers may independently govern the pilot's instruments, the copilot's, the engine indication and crew alert system, an autopilot, hardware drivers, and lastly, the Flight Simulator software.

CAPTAIN CARDIOLOGIST

Joseph Maldonado has spent the past year restoring the front section of an ex-TWA 727-200—flight deck, galley, lavatory, and 15 feet of the first-class cabin—and refurbishing it with airline paraphernalia such as in-flight magazines, silverware, playing cards, pillows, blankets, life vests, and barf bags. The Hatillo, Puerto Rico cardiologist plans on recreating the entire flying experience; when the simulator is finished, passengers will be able to watch scrolling terrain from their windows—or opt for an in-flight movie—as pilots fly the jet on a simulated route. Maldonado has prerecorded cabin announcements and even outfitted a mannequin with a flight attendant ensemble. He's also acquired a refreshment trolley. "I'm looking forward to having friends come over and eat a meal in the back as they await their turn to fly the jet," he says—and he doesn't just mean soda and a bag of peanuts. "We will serve full-course meals, as in the golden years of first-class."

COURTESY OF JOSEPH MALDONADO

Joseph Maldonado (with son) stripped the TWA livery to apply an American Airlines paint scheme.

LIGHTS! 737! ACTION!

Special challenges await those, like Matt Ford, who try to turn real aircraft into simulators. One is integrating monitor displays and converting avionics to respond to simulation programs and the multiple computers that drive them. Another is developing "flight loading," which determines the behavior of controls and governs force feedback—the yoke's resistance when pulling out of a dive, for example.

In 1998, Ford bought a 737-100 flight deck from a tear-down facility in Oklahoma, but for several years, it languished in pieces in his parents' Dallas garage. Once he got started, he put nearly $25,000 into the sim before he made his first flight, in February 2002.

Like others in the hobby, the Los Angeles lighting designer (who's earned two Emmys for work on the 1998 and 1999 Oscars) strives for authenticity. "I'm really committed to having every component be either a real part or an exact replica," he says. "I want a 737-NG [next generation] pilot to come in and see no discernible difference between my sim and the real thing." He's even acquired authentic "Boeing Gray" paint. "I love having friends come over and fly the thing," he says. "For them, it's like a ride at an amusement park."
www.737sim.com

COURTESY OF MATT FORD

Matt Ford's ex-Continental 737 now runs on six PCs instead of Jet A.

Left: Gauges and dials galore! Right: The functional oxygen mask.

COURTESY OF MATT WIETLISPACH (2)

ANALOG AMALGAMATION

Because digital displays easily interface with Microsoft's Flight Simulator series, most sim builders use computer screens for primary flight displays. Their absence makes Matt Wietlispach's sim unique; he refuses to use anything but analog gauges and dials.

For the avionics systems engineer, work and play are nearly identical. "I pretty much do the same thing at home as I do at work, but on a smaller scale and for much less money," he laughs. Working for an aerospace firm does have its rewards—Wietlispach uses discarded sheet metal scraps, instrument components, bolts, and lights for raw materials. Without them, he couldn't have built his simulator. "This stuff is beyond expensive," he says.

The sim in his Cedar Rapids, Iowa basement is a military hybrid. "There's probably at least 10 different aircraft in there," he explains. "If I tried to build a single aircraft type, I'd have to get parts only from that type," he adds, revealing the telltale compulsiveness of sim builders. "I have to have a drink before I fly it; otherwise I get obsessive about every defect."

Though the simulator can be rigged to fly combat missions, Wietlispach prefers the realism and terrain displays of the civilian-minded Flight Simulator 2002 program. "Flying in Chicago between buildings on Michigan Avenue at the speed of sound is quite a bit of fun," he says. Still, Wietlispach admits that building the sim is much more fun than flying it. He's recently added a pressurized G-suit and installed instruments to measure windshield temperature, engine nozzle position, and oil pressure. "It's an obsession. Sometimes I'll work on it all day without eating. Basically, I'm going to keep doing this until my hands break."
members.aol.com/wietlpachm/howto/

BY RALPH WETTERHAHN ILLUSTRATIONS BY DAN ZOERNIG

to SNATCH *a* SABRE

WHEN THE SUPERPOWERS FACED OFF IN THE AIR OVER KOREA, EACH SIDE WANTED WHAT THE OTHER ONE HAD.

The U.S. Air Force was able to determine precisely how the Soviet-built MiG-15 compared with its own premier fighter, the North American F-86 Sabre, because on September 21, 1953, two months after the cessation of hostilities in Korea, North Korean Lieutenant No Kum-Sok defected, flying his MiG-15 to Kimpo Air Base, South Korea. (The pilot earned a $100,000 reward, and his aircraft is now on display at the U.S. Air Force Museum in Dayton, Ohio.) The next day, the Air Force airlifted the MiG to Okinawa and sent two test pilots—Major Charles "Chuck" Yeager and Captain H.E. "Tom" Collins—to take its measure. During 11 test flights, the two pilots answered a question that is still being asked 50 years later: Which is better, the Sabre or the MiG?

At the start of the Korean War, the F-86 was the fastest airplane in the world: Its maximum speed was a blistering 685 mph. The MiG, at 670 mph, was not far behind. The Sabre had higher roll and turn rates than the MiG. But the test pilots found that the MiG had better acceleration, could climb faster, and could fight at a higher altitude.

With two 23-mm and one 37-mm cannon, the MiG packed a harder punch than the Sabre's six .50-caliber machine guns. But the Sabre had sharper aim. Its AN/APG-30 radar gunsight gave its pilots the advantage in ease of use and accuracy.

The Soviets had learned all this even before the Americans did. They had conducted comparisons of their own, thanks to a rare combination of circumstances and a focused opportunism.

Although U.S. Air Force Second Lieutenant Bill N. Garrett didn't know it at the time, the MiG-15 that took him out of the fight on October 6, 1951, was flown not by a Chinese or North Korean pilot, but by a Russian. The MiG pilot had hit Garrett's F-86A behind the cockpit and had damaged its J-47 engine and ejection seat. As Garrett struggled westward toward the Yellow Sea, where he planned to ditch and, with luck, get rescued, another MiG pilot spotted his stricken aircraft. This pilot too was Russian.

Throughout the Korean War, U.S. pilots traded rumors

BILL GARRETT WAS RESCUED BY AN SA-16 AMPHIBIAN, BUT ABOVE HIS F-86, A THREE-HOUR BATTLE RAGED.

about the enemies they faced in the air; they were never briefed that they were flying against Soviet pilots, but they suspected as much. What U.S. pilots didn't know was that every MiG flown in North Korea between November 1950 and December 1951 had a Soviet pilot at the controls. They didn't know that a veteran Soviet unit, the 324th Fighter Air Division, had arrived in China in April 1951. They didn't know that the ranks of the 324th were filled with some of the highest scoring Soviet pilots from World War II or that by October those pilots would down so many B-29s that the U.S. Far East Air Force would have to restrict the big bombers to night missions. And Garrett didn't know that a pilot of the 324th was following him to finish him off.

Captain Konstantin Sheberstov was patrolling in a formation of four when he spotted easy prey: a lone, wounded F-86. Sheberstov remembered the incident 45 years later for the Russian aviation journal *Mir Aviatsii*: "This F-86 was descending at an angle of 45–50 degrees with black smoke [trailing]. I started chasing him at the maximum speed. I caught up with him at an altitude of [3,300 feet] and from a distance of [975 to 1,150 feet] opened fire...." In trying to evade his pursuer, Garrett lost more altitude and was barely able to reach the mud flats along the coast, where he ditched the airplane. Here, on October 6, 1951, the Russians were presented with the trophy they had been trying to snare for months.

In the month before the first F-86s got to Korea, MiGs ruled the sky. Although World War II F-51 Mustangs were holding their own, they were no match for the Russian-built jets, and the U.S. straight-wing jets, Republic F-84s and Lockheed F-80s, were almost 100 mph slower than the MiG-15. But in December 1950 the Sabre arrived, like a Hollywood sheriff come back to town; they had barely joined the war when they shot down six MiG-15s in a single engagement on December 22.

The Soviets immediately set out to learn everything they could about the new enemy fighter. In the months that followed, Soviet intelligence agents monitored F-86 radio transmissions, interrogated Sabre pilots who had been shot down and taken prisoner, and reported their findings to the Soviet leadership. Premier Joseph Stalin himself gave the order to capture an F-86.

How the Soviets first attempted to carry out the order is not a proud moment in Russian aviation history. In April 1951, the Soviet Central Aero-Hydrodynamics Institute, a flight research center located at what is today Zhukovsky Airfield near Moscow, dispatched a special group of test pilots to a training base in Manchuria. The team practiced precision formation flying in MiGs, with the outlandish goal of boxing in an F-86, escorting it to Manchuria, and somehow forcing it to land. After a month of practice, the pilots joined the 196th Fighter Air Regiment, part of the 324th Fighter Air Division, at Andun, on the Manchurian side of the Yalu River, which formed a border between China and North Korea.

Experienced combat pilots of the Soviets' highest scoring regiment in Korea, the 196th made fun of the plan. Even today, the regimental commander, Colonel Yevgeniy G. Pepelyayev, derides the test pilots. When I spoke to him in Russia two years ago, he still had the pugnaciousness and arrogance at age 80 that characterized his career as a fighter pilot. He told me that the test pilots wanted to fly MiG-15s assigned to his regiment and offered to let the 196th count test-pilot victories as their own. Pepelyayev told them, "I don't need your victories and won't have any. You will be lucky if you manage to stay alive." Although Pepelyayev relented and allowed the use of his airplanes, his words were prophetic. He didn't need donated victories—he became the Soviet Union's top-scoring ace in Korea, credited with 19 kills (including Garrett's F-86; it was Pepelyayev who got the first hit). And the test pilots achieved no victories. During their first combat experience, on May 31, 1951, one of the senior test pilots was shot down. After their commander died in a crash landing at Andun airfield within weeks of the first loss, members of the group were spirited back to Moscow. Five remained and were absorbed into combat units, but the plan to corral a Sabre was quietly dropped.

Then on October 6, Bill Garrett bellied into a tidal pool on the coast of the Yellow Sea, and the Russians saw their chance.

Garrett was rescued by an SA-16 amphibian, but above his F-86 a three-hour battle raged as U.S. pilots tried to destroy the aircraft and Russian pilots fought them off. The Russians paid dearly for the prize. "We lost seven MiGs and didn't get any more Sabres," Pepelyayev said, "but the incoming tide covered the plane."

A Russian search team, which included Moscow representatives of the Mikoyan design bureau, used the MiG pilots' reports to locate the aircraft. Knowing it was only a matter of time before the Americans returned, the search team recruited 500 Chinese laborers to haul the wreckage from the water. The next day, as the team members labored to remove the wings, they had the advantage of an overcast sky, but U.S. ships at sea spotted the group and fired on them. An F-84 dropped through the clouds, causing the workers to scurry for cover on the levee, but the F-84 turned out to be a reconnaissance version and had no bombs to drop on the aircraft. That night, desperate to depart before dawn, the team continued dismantling the Sabre, finally finishing at four in the morning. The laborers loaded the pieces on trucks. Rolling toward Andun, the convoy hid in tunnels

THE AMERICANS "ALMOST GOT US," ONE OF THE MILITARY ENGINEERS, N.M. CHEPELEV, REMEMBERED. "THE DRIVER...WAS ALREADY APPROACHING THE TUNNEL WHEN WE NOTICED THE 'NIGHT WATCHMAN,' A B-26...."

during the day, hopping from one to the next each night, yet the prize was nearly lost. According to the 1998 article in *Mir Aviatsii*, one of the military engineers, N.M. Chepelev, rode in the lead truck, which carried the F-86's forward fuselage. Even though daylight was fast approaching, he decided to attempt to reach the next tunnel. The rest of the group elected to play it safe and stayed behind. The Americans "almost got us," Chepelev remembered. "The driver...was already approaching the tunnel when we noticed the 'night watchman,' a B-26.... We entered the tunnel at high speed as the B-26 fired several rockets at us. Fortunately, we were already about a hundred meters deep inside the tunnel, and the rockets could only penetrate for about 10 meters before hitting the walls."

Eventually, the convoy got its prize to Andun. The design group wanted the Sabre sent immediately to Moscow, but Pepelyayev persuaded the team to leave it at the base for a few days. "I sat in the cockpit. We all did," he said. "It was a well-laid-out cockpit, which created an impression that you were sitting in an expensive car." When the aircraft was finally sent on to Moscow, Pepelyayev recalled, someone sent back a complaint: "Couldn't you have washed the mud off the aircraft before sending it to us?"

The captured Sabre, serial number 49-1319, arrived at the Air Force Research Flight-Test Institute at Zhukovsky, 22 miles southeast of Moscow, in October 1951. Stalin knew that getting his hands on a Sabre would permit Russian engineers to copy and modify parts for fighter aircraft in a fraction of the time it would take to develop improvements from scratch. His intention had been to have the F-86 copied by an aviation design bureau, just as he had done with the B-29 after three of those aircraft had made emergency landings in Vladivostok during World War II (see "Made in the U.S.S.R.," Feb./Mar. 2001). But the inspection team at Zhukovsky, led by the highly respected test engineer Major Semyon Fradkov, concluded that the copying effort wasn't necessary. Engineers from the Mikoyan, Yakovlev, Tupolev, and Sukhoi design bureaus also examined the Sabre, and noted in their evaluation that the MiG-15 already was a good match for the F-86 and that the MiG-17, about to go into production, was more advanced.

According to Yakovlev's Eugenji Adler, only one engineer dissented: V.V. Kondratyev, from the Central Aero-Hydrodynamics Institute. For his trouble, Kondratyev was tasked with the project of reverse-engineering the Sabre, but the design bureau that was to be created for the purpose never came to be, the effort lost among the many projects jockeying for attention and funding in the final years of Stalin's regime. (Stalin died in 1953.)

Meanwhile, the Air Force Research Flight-Test Institute proceeded with its analysis of the F-86's systems. A team of engineers removed each item and measured, photographed, and drew wiring and engineering diagrams of it. One of the systems that most interested the Russian engineers was the gunsight. Senior Lieutenant Vadim Matskevic, who worked in the air force engineering department, got the job of comparing the F-86 gunsight system with the one on the MiG-15.

ONE OF LIEUTENANT COLONEL STEPAN MIKOYAN'S RESPONSIBILITIES WAS TESTING SABRE SYSTEMS AND AVIONICS THAT HAD BEEN INSTALLED ON A MIG-17 RESEARCH AIRCRAFT.

The F-86 had a Sperry APG-30 radar gunsight, which was extremely accurate up to a range of about 3,000 feet and able to measure the range and compute the lead time required even while the target was maneuvering. The MiG-15, on the other hand, had a manual system that had been designed in 1939. In Korea, many Sabre pilots credited their gunsight with the advantage they had over MiGs. Matskevic said as much in his report, concluding that the F-86 sight was better than the Soviet design. But questioning a decision in Stalinist Russia—the decision, in this case, to field a fighter with an inferior system—was a dangerous business. Matskevic's opinion earned him some 30 denunciations from other engineers.

Matskevic is still proud of the work that evolved from his report. Today a retired engineer with horn-rimmed glasses living on a pension in Moscow, he talks about the pressure he felt while he was at the institute. Believing he could be kicked out of the service, sent to Siberia, or worse, Matskevic says he worked feverishly to develop a counter to the F-86 gunsight. Matskevic is excitable, especially when describing his achievement; he puffs out his chest, his voice rises in triumph, and he perhaps overemphasizes his own importance. But he is one of the few from the era who was denounced and still saved his own neck, so his immodesty is understandable.

He designed a warning system that detected the signal from the Sabre's gunsight and alerted the pilot that his aircraft was reflecting the signal back to a pursuer. Based on the same technology as today's police-radar detectors, the system was a simple receiver, mounted on the tail.

Flight testing the device became the chore of Lieutenant Colonel Stepan Mikoyan, nephew of the renowned Mikoyan-Gurevich Design Bureau chief, Artem I. Mikoyan. Mikoyan had fought in Moscow and Stalingrad during World War II. He then attended the Zhukovsky Air Force Academy in Moscow, graduating with honors in 1951 to become a test pilot at the Research Flight-Test Institute.

Mikoyan, now 81, is an elegant, accomplished man with a full mane of silver hair and a mustache. He smiles often, his face showing the crow's feet of a man who has spent many, many hours squinting into the sun from beneath a fighter canopy. Though retired with the rank of lieutenant general, he still goes to work at the institute every day.

One of Mikoyan's responsibilities was testing Sabre systems and avionics. He recalled for me how he and test pilot Igor Sokolov tested Matskevic's warning device. To prove his concept, Matskevic set up the radar emitter from the captured Sabre on the roof of one of the institute's tall buildings and mounted his warning device on a MiG. Every time Mikoyan and Sokolov flew the MiG over the building, "we heard a low-pitched 'howling' in the earphones," Mikoyan recalled. "As the distance from it grew, the noise became higher in pitch, but lower in volume. Even so, it remained perfectly distinct within seven or eight kilometers [four to five miles]."

In May 1952, Matskevic took 10 sets of his new invention to Korea and began installing them in MiG-15s. It took about three hours to complete each installation.

Because it occasionally gave false warnings, pilots initially distrusted the device. Many just turned it off, Matskevic said. But he was soon vindicated: A regimental commander flying over the Yalu heard the device give off a faint tone. He checked his six o'clock position and saw nothing. The tone grew louder, so the pilot craned his neck around to look again. Still nothing. He decided the system was acting up, so he shut it off. A minute later, feeling uneasy, he turned it back on. Now the tone was howling. He looked back in time to see two F-86s closing to gun range. As the Sabres opened fire, the MiG pilot banked sharply and escaped with only minor wing damage. From that point on,

the word spread. "We saved a lot of pilots," Matskevic said. The system also saved Matskevic's career. He received the Soviet Red Banner, awarded for meritorious service, and a tribute from North Korea. His warning device and its derivatives became a standard equipment on all Soviet fighters.

As more components from the captured F-86 were removed and cataloged, they were installed on test bed aircraft at the Soviet test institute. As a result of the evaluations, several conducted by Mikoyan, the Soviets modified their existing fighters and incorporated some features into future models. The MiG-15bis, for example, already in production, was given a larger speed brake and new hydraulic systems to operate the elevator and ailerons. The larger brake and aileron boost system were also incorporated into the MiG-17. The small F-86 accelerometer, for measuring G forces, was adopted and installed on the MiG-19 and follow-ons.

While work on the F-86A continued in Moscow, an F-86E, serial number 51-2789, flown by World War II ace Walker H. Mahurin, was downed in Korea by flak in July 1952. Mahurin, then a wing commander, crash-landed. He sustained a broken wrist and was captured and remained a prisoner until just after the armistice in 1953.

His aircraft, though it was in worse condition than Garrett's F-86A, was recovered and dismantled, and the parts were sent to Moscow. The evaluations of its systems were conducted after the war.

In the F-86A model, cables connected to hydraulic actuators moved the control surfaces, but the -E eliminated the cables in favor of a completely hydraulic system for operating control surfaces. The -E also used an all-moving horizontal stabilizer. The combination improved maneuverability at high speeds without the need for trim tabs. Artificial feel was built into the aircraft controls using weights and bungee springs, which let the pilot feel normal stick forces that were still light enough for superior combat control.

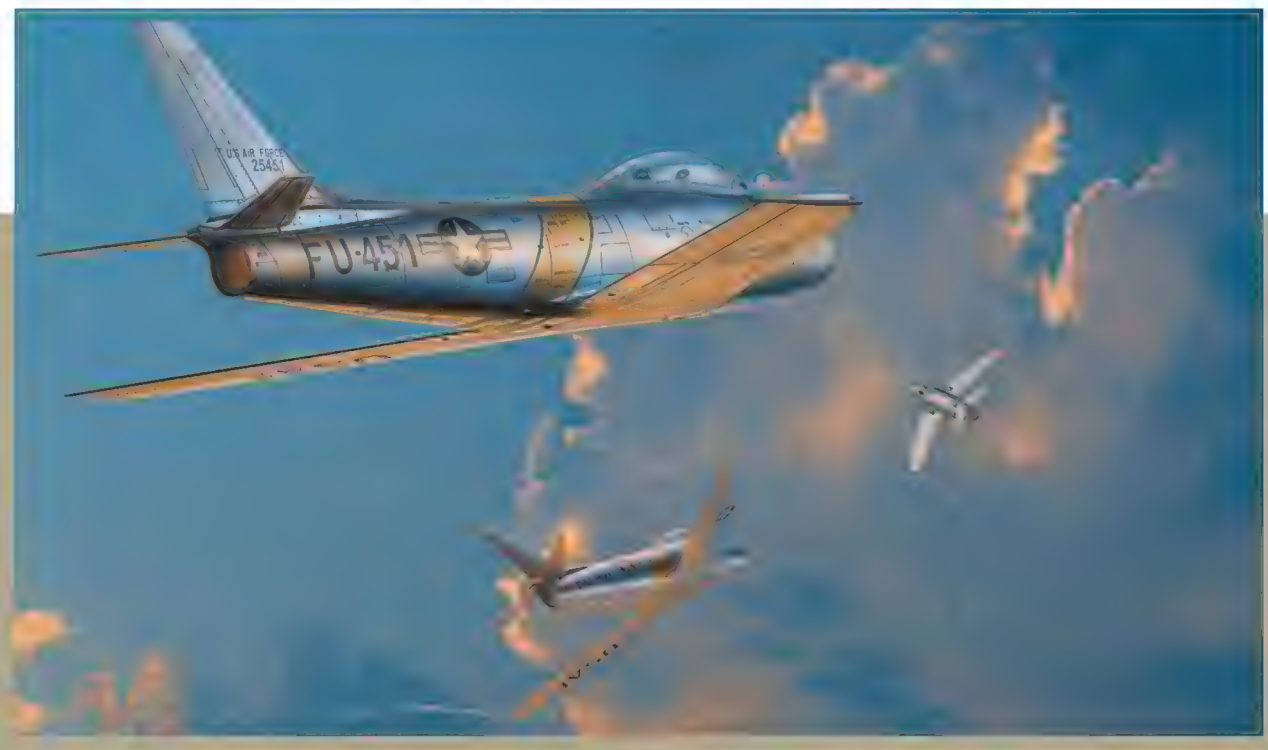
A prototype of the MiG-17, dubbed SI-10, was selected to evaluate the features of the new F-86E models. After the design bureau test pilots made several flights at Zhukovsky airfield, Mikoyan ferried it to the Chkalovskaya airfield and in June 1955 began testing it. One of the the F-86E's modifications included the leading edge flap system. "The leading edge flaps improved maneuverability to some extent, but they were not adopted, I think because production of the MiG-17 was ceasing then," Mikoyan told me. "They were not used on the MiG-19 either, probably because of the greater sweep angle of its wings [almost 60 degrees]."

The fully movable stabilizer was also tried on the MiG-17. When Mikoyan flight tested it, at a three-G load factor, he let go of the stick to test the aircraft's dynamic stability. He expected the MiG to porpoise slightly and return to stable flight, but he got a surprise. "The aircraft pitched down so sharply that I was tossed up from my seat and bumped my head against the canopy," he said. "Then it pitched up, and I was pressed down into the seat. After a series of such violent and hardly bearable jolts, I finally decided to get hold of the stick, and the aircraft steadied down. My head was booming like a church bell and ached—I was only wearing an ordinary leather helmet. When the instrument readings were studied afterward, it turned out that there had been nine up-and-down jolts in eight seconds, with the positive load—pressing me into the seat—up to 10 Gs and the negative up to –3.5 Gs."

Mikoyan borrowed one of three U.S. "crash helmets" recovered in North Korea and flew a second test. "The whole thing happened again, the only difference being that my head did not ache quite as much," he said. The stabilizer modification, Mikoyan added, was not adopted for the MiG-17. However, the all-movable stabilizer was installed on the MiG-19 and later Soviet fighters.

One of the most significant adaptations the Soviets made after capturing the Sabres and Sabre pilots was the introduction of G-suit systems, which enabled Russian pilots to handle the increasingly formidable MiG and Sukhoi fighter jets to come. With the addition of G-suits, the Soviets improved the performance of the most lethal system in a combat aircraft: the pilot.

HE LOOKED BACK TO SEE TWO F-86s CLOSING TO GUN RANGE. AS THE SABRES OPENED FIRE, THE MIG PILOT BANKED SHARPLY AND ESCAPED WITH ONLY MINOR WING DAMAGE. FROM THAT POINT ON, THE WORD SPREAD.



How Things Work:

Infrared Cou

by Sam Goldberg | Illustrations by John MacNeill

On November 28, 2002, just moments after takeoff from Mombasa, Kenya, Israeli vacationers felt their chartered Arkia Airlines Boeing 757 shudder as it flew through the wakes of two Soviet-designed SA-7 missiles that were meant to bring it down.

Passengers hardly noticed the bump, but as the cockpit crew watched the white contrails arc away, they instantly grasped the situation.

For five hours the crew said nothing. Only when the flight was minutes from Tel Aviv were the passengers informed that terrorists had fired on the aircraft from an area around Moi International Airport. The relieved passengers broke into celebration, but the press began to wonder how two SAMs could miss such a large, slow target.

One theory is that poorly trained gunmen fired the shoulder-launched missiles from the wrong distance or at the wrong angle. It's possible that the two heat-seekers may have locked on to a glint of sunlight or a wing's edge that was too thin to hit, and there's a good chance that their decades-old batteries were nearly dead. But there may have been other factors at work that affected the two missiles.

A few secretive Arkia, U.S., and Israeli officials know whether the airliner carried infrared countermeasures. (One passenger's report of a small explosion near the wing suggests that the 757 may have dispensed flares as decoys.) Arkia, the Federal Aviation Administration, other airlines, and aircraft manufacturers don't encourage discussion of current or planned safeguards against shoulder-fired man-portable air defense systems (manpads) like the SA series and the U.S.-made Stinger.

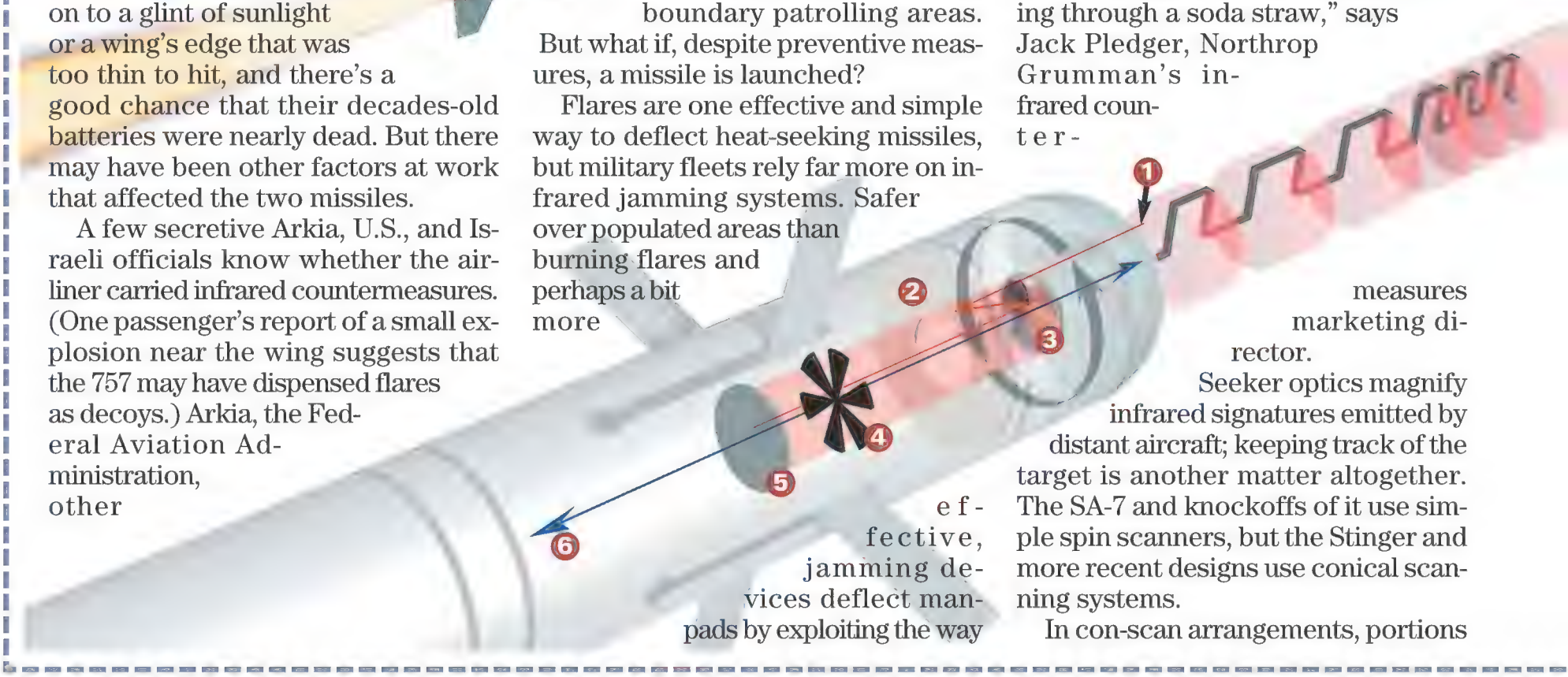
Congress recently began working on legislation to explore the best anti-missile measures and equip the U.S. jetliner fleet. Recently the Transportation Security Administration began surveying major airports to assess the risk at each. Some airports have expanded their boundary patrolling areas.

But what if, despite preventive measures, a missile is launched?

Flares are one effective and simple way to deflect heat-seeking missiles, but military fleets rely far more on infrared jamming systems. Safer over populated areas than burning flares and perhaps a bit more effective, jamming devices deflect manpads by exploiting the way that the missiles track their targets.

To lock on to a target, a manpad gunner must physically point the system at an aircraft as the missile's seeker passively searches for the most powerful source of infrared radiation in its limited view—usually a heat source such as a jet exhaust nozzle or heat plume. "Since their primary job is to stay locked on," says Darrell Lamm, chief of Georgia Tech Research Institute's Threat Analysis and Countermeasures Branch, heat seekers' fields of view "are usually small to prevent distraction from competing sources."

"We usually use the simile of looking through a soda straw," says Jack Pledger, Northrop Grumman's infrared countermeasures marketing director.



Seeker optics magnify infrared signatures emitted by distant aircraft; keeping track of the target is another matter altogether. The SA-7 and knockoffs of it use simple spin scanners, but the Stinger and more recent designs use conical scanning systems.

In con-scan arrangements, portions

ntermeasures

of light ❶ collected by a Cassegrainian primary mirror ❷ are reflected by a secondary mirror ❸ through a chopper reticle ❹ and onto an infrared detector ❺. The secondary mirror swivels about the missile's roll axis ❻ (manpad missiles, like bullets, spin in flight for stability) and must make a full revolution for the detector to be exposed to the seeker's entire view of the sky. After infrared energy is focused by the secondary mirror, it passes through the chopper reticle, a disc with a rotor-like paint scheme—opaque blades alternate with transparent slots. The reticle chops the infrared energy into a series of "ons" and "offs" that help determine pointing error—the difference between the missile's current trajectory and an intercept course.

When a target is directly lined up with the missile's optics, it traces a perfectly centered circle ❼ through the reticle and onto the detector in time with its reflection off the spinning secondary mirror. To the signal processor linked to the detector, the target's path will translate into ons and offs of equal duration ❽ as it is chopped into pulses by the reticle's fan pattern. The circular path of an off-target signature ❾, on the other hand, will result in waveforms of varying widths ❿; the more off-center the signature, the more pronounced the variations.

The guidance system tracks the section of the sky where the secondary mirror is sweeping. Programs in the system pair this information with the waveforms and move the fins to steer the missile. As Paul Handwerker, director of BAE Systems business development for countermeasures, explains, "The missile is always, constantly working to put the target back in the center of the reticle."

Jammers blind the missile to the target aircraft by bathing the seeker head with intense infrared radiation that washes out the aircraft's own signature. The comparison of the jamming energy to the aircraft's energy is commonly expressed as the J-to-S ratio. J is the strength of the jamming signal and S is the strength of an aircraft's signature. "You need to have a larger J than the S to be effective," says Pledger. "You need to put out more energy than the signature of the target to effectively jam the missile."

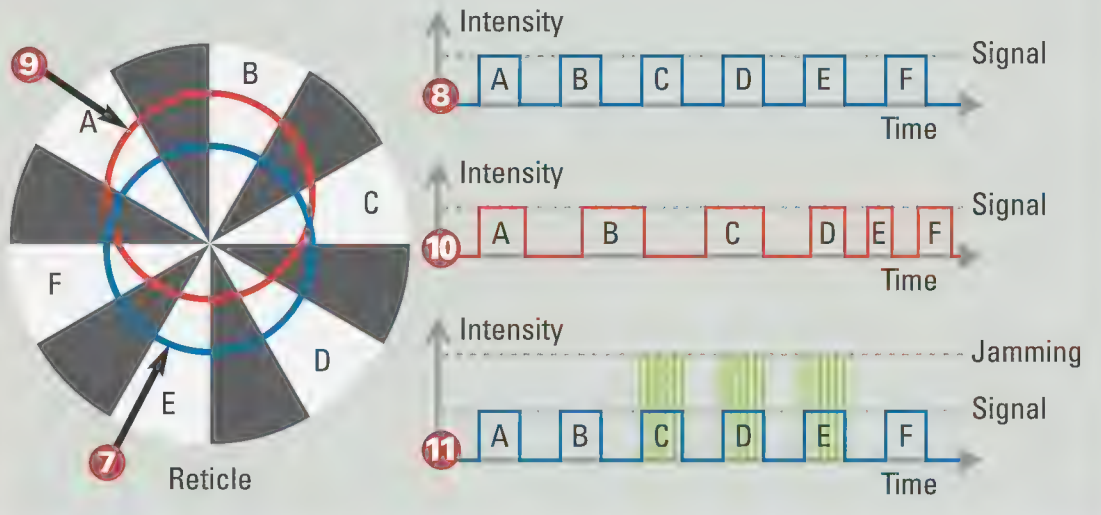
By pulsing energy like a powerful strobe light, jamming devices fool missile guidance systems by projecting extra ons and offs into a missile's infrared detector ⓫, breaking up the target processing. Once a manpad's lock has been broken and the missile has overshot the target, the seeker's field of view is too small for the missile to reacquire the target.

Different types of jamming countermeasures trade power and effective range with other factors. Omnidirectional lamps operate continuously and create entire hemispheres of protective jamming, though their signal at any given point in the sky is relatively weak. And because they send out a constant torrent of energy, they use a lot of electrical power. Directed systems are more effective and more energy efficient, using focused beams directed at a particular sector of the sky or lasers pointed at the seeker head. Pledger says directed beams can have a J-to-S ratio of between 2:1 and 50:1, while lasers can be 300 to 2,000 times more powerful than their host aircraft's signature. But the pointing feature of directed systems requires complex missile detection hardware. Multiple threats and highly maneuverable supersonic missiles are a challenge for directed systems.

The cost to equip the world's airliners makes it unlikely to happen anytime soon, but some comfort can be found in the fact that airliners can keep flying after losing an engine.

Overruling the Target's Signal

Jammers pulse infrared radiation of higher intensity through reticle openings to create waveforms that confuse guidance systems.



For exploring Jupiter and beyond, it's the only way.

by Ben Iannotta

NASA GOES NUCLEAR

Officials at NASA headquarters in Washington, D.C., were batting around names for their soon-to-be-announced nuclear program last fall when Administrator Sean O'Keefe offered a suggestion. Why not call it Project Prometheus, after the giant in Greek mythology? It was Prometheus, after all, who brought fire, and with it civilization, to humankind. So far so good. But the story has a disturbing end. For Prometheus' effrontery, Zeus had him chained to a rock, helpless to defend himself as an eagle pecked out his liver, over and over, day after day.

"We had several rounds of e-mails with the Administrator over whose liver was going to be pecked out," jokes Al Newhouse, a former Navy nuclear engineer who heads Project Prometheus at NASA headquarters. "That was funny, except it was always mine."

After decades of false starts and dashed hopes, Prometheus marks the return of nuclear reactor development for U.S. spaceflight. In June 1993, after 10 years of work, Congress voted to end the last space reactor project, called SP-100, before it even got to the point of ground testing. Newhouse remembers the day well. He had moved over from the Navy to join the Department of Energy as SP-100 director. "I was put in the position of shutting down the program that I was brought in to nurture and support," he says.

Now O'Keefe, a former Secretary of the Navy who is familiar with nuclear-powered submarines and aircraft carriers—and whose father was a nuclear sub engineer—has recruited Newhouse and other Navy veterans with nuclear expertise to run Prometheus, which will produce advanced systems for both power and propulsion.

This time Newhouse hopes things will be different. The trouble with SP-100, he says, was that it never had a guaranteed customer. While the reactor was in development, both of its intended users—Ronald Reagan's "Star Wars" space weapons program and the (short-lived) proposal of his successor, George Bush, to send astronauts to the moon and Mars—fell by the wayside. This time, though, NASA has asked the energy department to build a reactor for a specific purpose—to power a robotic mission to explore three moons of Jupiter as early as 2011. After that, it will provide electricity for future planetary spacecraft far more capable than past Vikings and Voyagers, which used either solar power or small plutonium batteries.

Prometheus is a gamble, both technically and politically—because launching radioactive material is likely to generate protests and create a public relations problem for NASA. But many people, O'Keefe foremost among them, believe nuclear power is the only way for NASA to take the next step in space

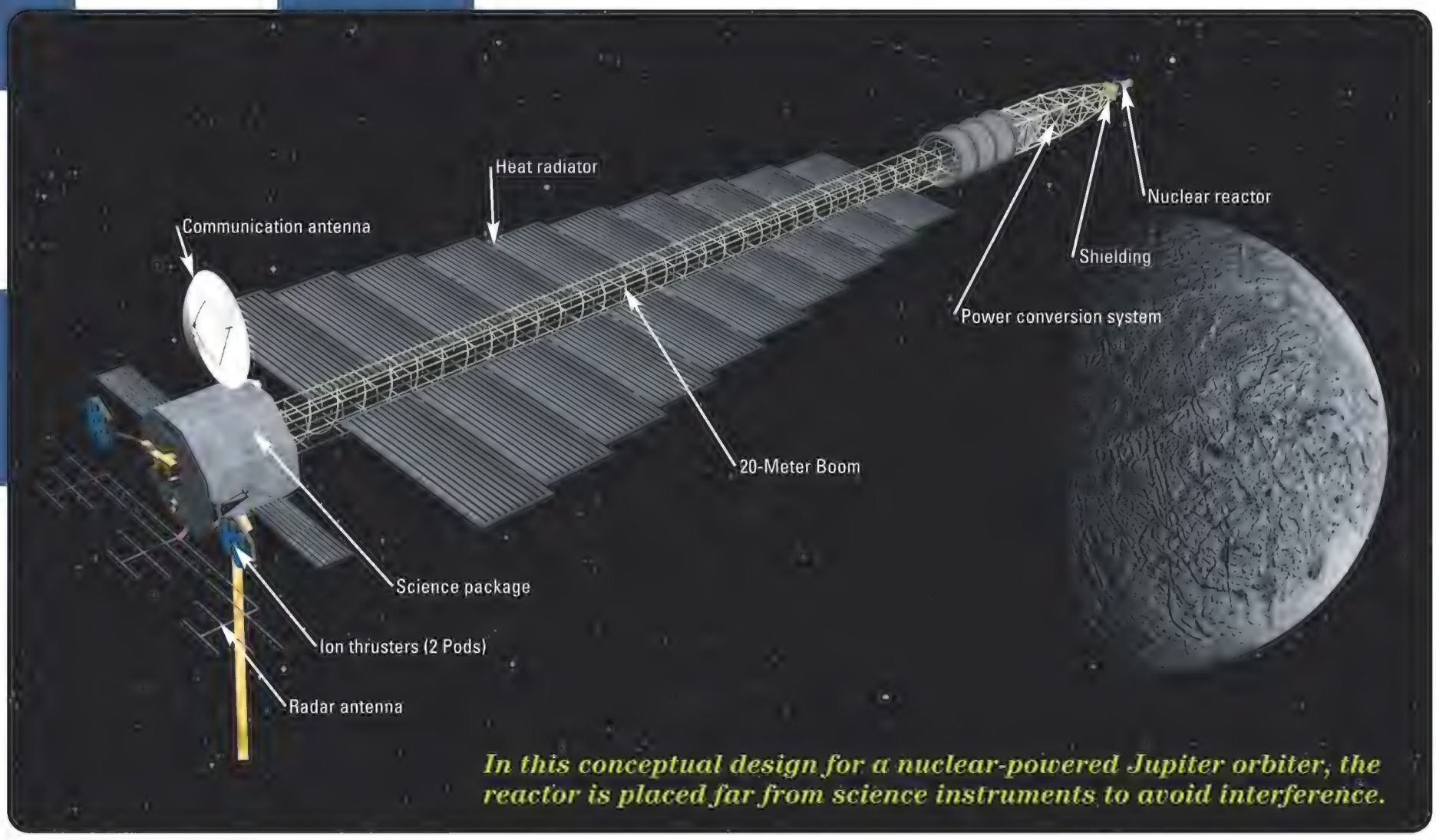
exploration. Agency science chief Edward Weiler recently told a committee of the National Research Council that O'Keefe "not only calls it the future of planetary exploration, he calls it the future of NASA."

If you compare the proposed Jupiter Icy Moons Orbiter (JIMO) to the Cassini spacecraft now headed for a July 2004 rendezvous with Saturn, it's easy to see what he means. Cassini's electricity comes from radioisotope thermoelectric generators, which have been standard equipment on spacecraft venturing too far from the sun to rely on solar power. The RTGs on Cassini produce power from the decay of plutonium and generate about 900 watts, enough electricity to power nine standard light bulbs. JIMO's nuclear reactor will produce 100 *kilo*watts, or several times the average daily household use.

For planetary exploration, that kind of power output is revolutionary. It means data will come back to Earth in unprecedented volumes—120 CD-ROMs' worth for the entire mission, compared to a couple of floppy disks for Cassini. Instead of observing Jupiter's moon Europa for a few hours at close range, which had been the plan for a

NASA GLENN RESEARCH CENTER (2)

The glow of success: NASA has already flown 12-inch ion engines (right, shown firing). Ions shoot out the holes in a circular grid, producing a small but steady thrust.



In this conceptual design for a nuclear-powered Jupiter orbiter, the reactor is placed far from science instruments to avoid interference.

JPL

non-nuclear mission NASA was considering as recently as last year, JIMO will study three Jovian moons for a total of 180 days. And it can carry a much more powerful sounding radar to probe for an ocean suspected to lie beneath Europa's icy crust.

First, though, Prometheus has to deliver the fire. On a conceptual level, a space nuclear reactor would work much like a reactor on the ground. Neutrons given off by a radioactive fuel, in this case uranium, would strike other uranium atoms, which would then split to create more neutrons, perpetuating the reaction and generating heat, which would be absorbed by a coolant and converted to electricity.

But most nuclear reactors aren't launched on rockets from the densely populated Florida coast. So Department of Energy engineers will have to assure critics that in the event of a launch accident, a space reactor won't suddenly start splitting atoms. "Safety becomes the driver in the reactor design," says Earl Wahlquist, head of DOE's Office of Space and Defense Power Systems in Maryland.

In a space reactor, the fuel elements would be surrounded by neutron-reflecting materials. Without the reflectors in place, there aren't enough neutrons bouncing around to cause a chain reaction. So engineers would devise a system to move the reflectors into place to start the reactor, then back them out to stop it. With the reflectors in safe mode during launch, the uranium fuel would be no more than "marginally radioactive," Wahlquist says. If the rocket exploded on the launch pad or suffered some other catastrophic failure on its way to orbit, "the rocket fuel would be more toxic than the uranium," he says.

JIMO and its reactor would be launched on a conventional rocket to an altitude of just over 600 miles; only then would the reactor be turned on. At that altitude, say NASA officials, if something went wrong after controllers start the reactor, it wouldn't pose a threat to people on the ground. SNAP 10A, a reactor-powered spacecraft launched by the U.S. military in 1965, has been circling Earth ever since malfunctioning on its 43rd day of operation. About 1,000 years from now, its orbit will have decayed to the point where the spacecraft will reenter the atmosphere. By then, its radiation will have dissipated, and "we think it will be [just] a hunk of metal," Newhouse says.

DOE expects to build the JIMO reactor at one of its facilities, most likely the National Environmental and Engineering Laboratory in Idaho or the Argonne National Laboratory in Illinois. Wahlquist says it won't be a simple matter of resuming work on SP-100; other designs will also be considered. For example, SP-100 used liquid lithium metal for its coolant, but Prometheus may use a light gas like helium, or vapor transported through heat pipes. Whatever the choice, the reactor will have to be as light as possible, a requirement for any hardware that is space-bound.

Once the JIMO reactor is turned on, the heat it produces will be converted to electricity to drive a new type of thruster that propels the craft with a glowing stream of ions. "This is not a nuclear rocket," Newhouse says, still chafing from an article in the *Los Angeles Times* last year that failed to distinguish Prometheus' nuclear electric engines from more advanced—and controversial—nuclear thermal rockets, which would circulate hydrogen through a reactor and spew the exhaust out a nozzle. JIMO's reactor is only a power source, not part of the engine itself.

Stanley Borowski, a 15-year veteran of the agency's Glenn Research Center in Ohio and unofficial keeper of the nuclear flame at NASA, has another nit to pick. The word "is pronounced 'nu-clee-ar,' " he says. "It's not 'nook-

u-ler,' which still a lot of people say." After SP-100 was scrapped and all talk of nuclear-powered Mars missions ended in the early 1990s, Borowski, a nuclear engineer with a Ph.D., retreated into the bowels of the Glenn center, where he continued working on low-level internal studies. Now his field is hot again. The budget plan that NASA sent last summer to the White House Office of Management and Budget, where O'Keefe used to work, included a stepped-up nuclear program. Having seen official excitement rise before, only to fade away quickly, some nuclear proponents were skeptical that the new plan would go anywhere. "Quite frankly, I didn't think we had a ghost of a chance," Newhouse says, "but it was approved." Prometheus was born.

Engineers Dave Manzella and Rob Jankovsky bend down to look through a porthole at the base of a white schoolbus-size vacuum chamber at the Glenn center. Inside the tank, a circular rocket engine about the size of a large pizza gives off a steady, pale blue glow, like a TV in a darkened room. The only sound is the hum of the chamber itself. No need to hide in a blockhouse from the thundering rocket blast. In fact, the thrust from this engine is imperceptible to all but the sensitive disk it's mounted on.

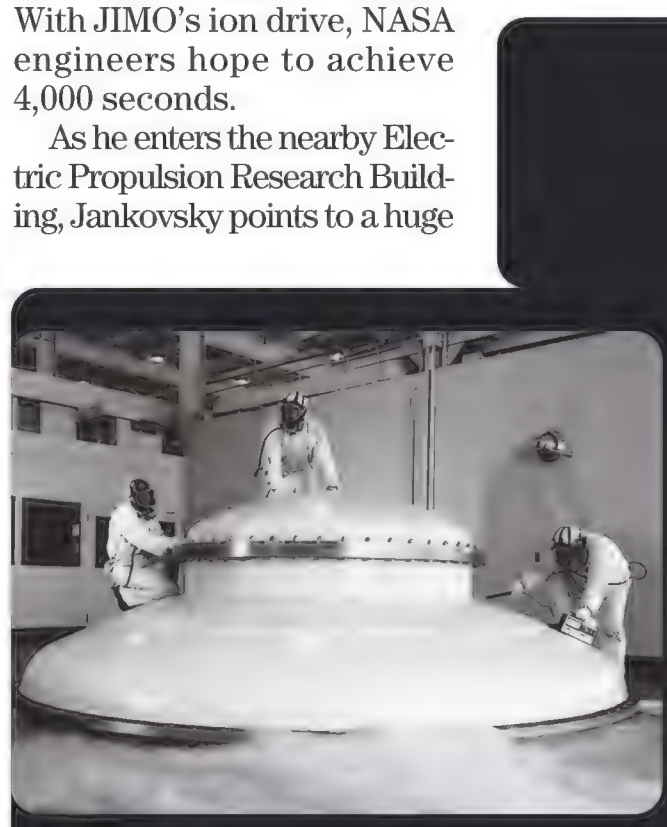
It will be just such an engine, powered by a nuclear reactor, that pushes JIMO toward Jupiter and lets it maneuver through the Jovian system with a new kind of nimbleness. The thrust produced by ion propulsion—the slow, steady expulsion of ions to accelerate a spacecraft—ranges from a fraction of an ounce to three pounds, minuscule by the standards of most liquid-fuel rockets. Cassini's twin thrusters, for example, produce 100 pounds each. But, explains Jankovsky, chief of Glenn's onboard propulsion branch, the ion engine would be so fuel-efficient that it could run continuously, building up speed and eventually outpacing chemical rockets.

When the Galileo probe approached Jupiter in 1995, it fired its liquid-fuel main engine for 49 minutes to slow down so Jupiter's gravity could pull it into orbit. After that big burst, Galileo had only enough fuel left for minor tweaks to its trajectory. Most of the subsequent course correction came from carefully timed gravity-assisted swing-bys of the Jovian moons. "If you look at a chart of the Galileo orbits, it looks like a line drawing of a flower where each orbit represents a petal of the flower," explains Ron Greeley, a planetary geologist at Arizona State University.

Mission designers measure such maneuvers in terms of delta-V, or change in velocity—basically, how much energy is needed to change a spacecraft's speed and direction. Cassini carries enough fuel to provide a total of 6,500 feet per second of delta-V over the lifetime of the mission. JIMO may have 30 or 40 times that. "With JIMO, we'll orbit Callisto, then slip over and orbit Ganymede, and finally over to orbit Europa," says Greeley. Such dramatic, energy-demanding orbit shifts were well beyond the capability of earlier planetary spacecraft, because the trajectories would have required many times more liquid fuel than they could affordably carry.

The efficiency of a rocket is generally given in terms of specific impulse, measured in seconds. A typical planetary spacecraft thruster might have a specific impulse of 300 seconds. "People who build chemical rockets would kill for a couple extra seconds of specific impulse," says Jankovsky. With JIMO's ion drive, NASA engineers hope to achieve 4,000 seconds.

As he enters the nearby Electric Propulsion Research Building, Jankovsky points to a huge



Ion drives go way back. Above: preparing to test a vacuum tank at the Lewis (now Glenn) center in 1961. Below: Thruster firing, 1957.

RIGHT: BILL BOWLES; ABOVE: NASA

circular engine in a corner. It measures five feet across and looks like the housing of a large industrial fan. Engineers tested this 200-kilowatt ion engine in a vacuum tank here in 1967, back when it was assumed nuclear reactors would be generating millions of watts of electricity for future missions to Mars.

The engines being developed in this building are far less ambitious, but still an advance over the ion engines that have flown in space so far. At one end is a cathode tube that spits out electrons. They collide with a neutral gas, in this case xenon, knocking off more electrons and creating positively charged xenon ions. Other fuels could be used—krypton gives off a greenish glow, neon glows red. Xenon is popular because its electrons orbit farther from their nuclei, and that makes them easier to bump.

In 1998, a NASA technology demonstration mission called Deep Space 1 used a xenon engine; solar panels instead of a nuclear reactor supplied electricity. Although ion propulsion had already flown on U.S. commercial satellites and dozens of Russian military satellites, its use on DS1 was the first time it was included on a spacecraft dispatched beyond Earth orbit—in this case, to a comet and asteroid. The ion drive worked like a champ. The test proved that the engine could be throttled up or down, that its exhaust would not corrupt scientific readings, and that the ions wouldn't short out electronics or block radio signals.

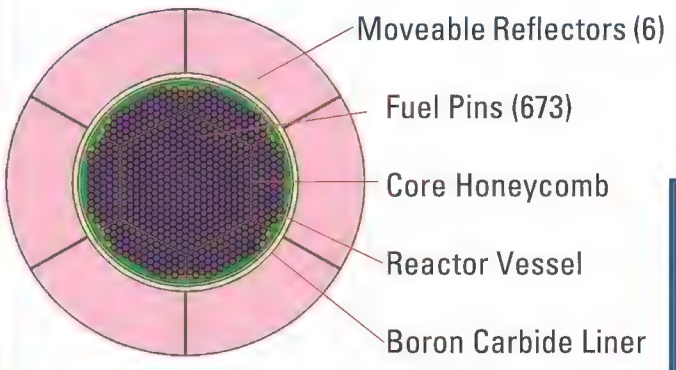
But DS1's engine was not a powerful one, even by ion thruster standards. And although it ran for 678 days and was still going when NASA ended the mission in 2001, that wasn't long enough to demonstrate the years-long operation required for the JIMO mission.

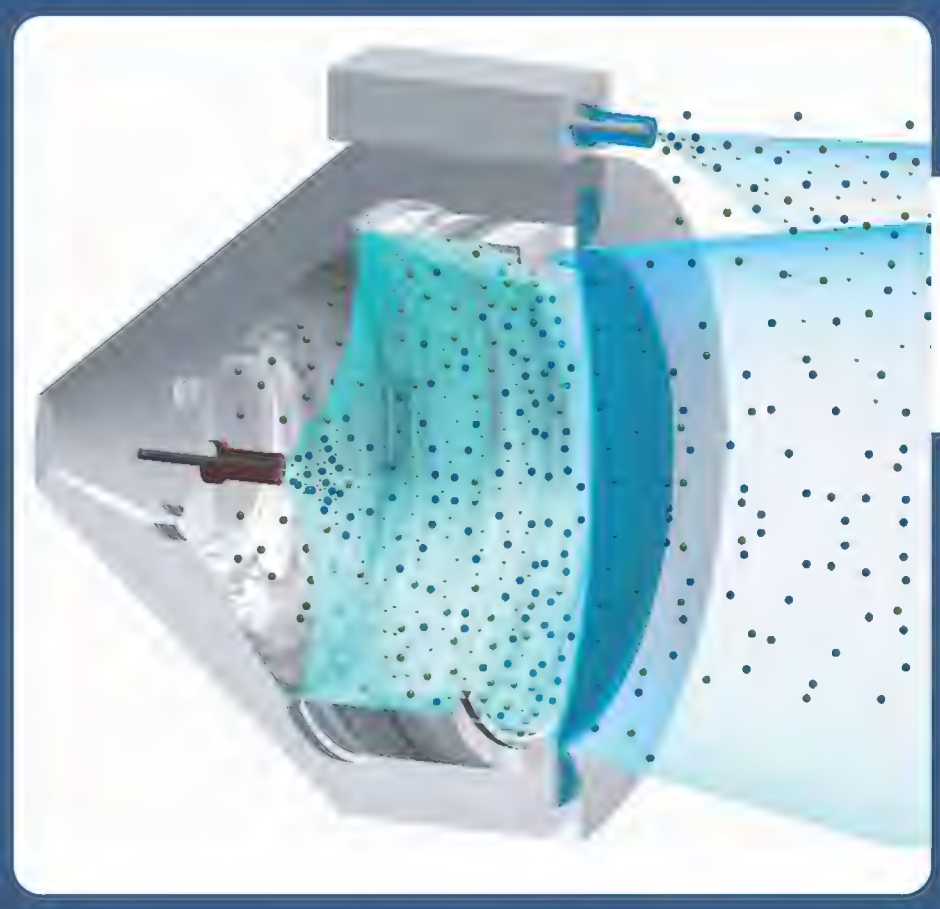
So, says Mike Patterson, who co-built the DS1 engine with fellow Glenn engineer Bob Roman, "when somebody asks, 'Why are you still working on ion thrusters—I thought you flew on DS1?' I find that laughable. It's like saying, 'You're still working on chemical rockets? I thought Robert Goddard did that in 1927.' We're in the infancy."

Patterson is working on the Next Generation Ion Propulsion System, a larger, more powerful, and more fuel-efficient version of the DS1 engine. That thruster was about 12 inches wide and operated at 2.3 kilowatts. The new engine will be about 16 inches wide, consume up to seven kilowatts, and perform with 28 percent greater efficiency. Patterson's goal is to build on the DS1 work without leaping too far, too fast. One major reason is that NASA doesn't have the budget it did in the glory days of its youth. "Back in the '60s, when the guys were working on the [five-foot-wide engine], I suspect they thought we were probably going to go to Mars by 1975 or something like that," he says. "It just didn't happen."

The greatest challenge facing Patterson's team is proving that an ion engine can operate for 10 years. "That's 88,000 hours of operation," he says. "If you look at your standard automobile engine, your car only lasts about 2,000 hours. And you're constantly maintaining it. These we can't maintain."

No one knows how long an ion engine can last. At NASA's Jet Propulsion Laboratory in California, engineers continue to run an identical flight spare of the DS1 engine in a test chamber. As of January, it had operated for 27,000 hours and consumed over 430 pounds of xenon, says DS1 program manager Marc Rayman. NASA engi-





Neutrons and Ions

A space nuclear reactor (above) would surround uranium fuel pins with reflectors that are moved into place to bounce neutrons back toward the core, which controls the rate of the reaction. An ion engine at work (right): Electrons (yellow particles) ejected from a cathode (left) interact with xenon gas (green), producing a stream of xenon ions (blue) for thrust. The boxy component at top injects electrons to neutralize the exhaust so it has no net charge.

LEFT: DEPARTMENT OF ENERGY; BELOW: MATT DOMONKOS / NASA GLENN RESEARCH CENTER

neers were debating how long to keep the test going. "If you run it to failure, you may destroy evidence to say 'This is the rate at which it erodes,' " Al Newhouse says.

Designers of traditional chemical-fuel rockets have the luxury of firing test engines for one and a half times the duration they will eventually operate in space. That isn't possible for an ion engine intended to run for 10 years. So finding a cost-effective and accurate way to predict lifetime without firing thrusters for their full duty cycle is critical. "If we make a mistake we won't see for six or eight years, then we'll be six or eight years behind," Patterson says. And if it happened during the actual mission, JIMO could be lost in space. The team is working on a system that uses lasers to measure concentrations of particles as they sputter off the electrodes during short tests. From that data, engineers would extrapolate the expected engine lifetime.

Patterson's team also hopes to boost the power of its engine beyond that of the DS1 thrusters. In the smaller engine, ions were shot through a circular molybdenum grid that looked a little like the screen filter in a kitchen faucet. To make a more powerful engine, Patterson can't simply shoot more ions through a grid of the same size and material—the molybdenum would erode too quickly. So he is experimenting with carbon graphite grids that are more resistant to so-called sputter erosion. A DS1-type engine built with graphite grids might erode seven times slower, says Patterson. Engineers would then have the choice of running the engine longer at the same power, or working it harder.

In all likelihood, a JIMO-type mission would be powered by a cluster of ion engines that would take full advantage of the 100 kilowatts of power produced by the nuclear reactor. One option would be to line them up in an array along a boom. "Is it going to be three thrusters, five thrusters, or 10 thrusters?" Jankovsky asks. At the moment no one knows, because no one knows for sure how much thrust a single ion engine will be able to produce.

But there's little doubt that in terms of mission design, the combination of nuclear power and ion propulsion offers a sharp departure from the past. Prometheus and JIMO could open up whole new types of missions for exploring the solar system. "For example, if one were to go to Saturn with a follow-on to Cassini, you could envision the possibility of [placing] landers down on the solid parts of [Saturn's moon] Titan," Greeley says. Multiple atmospheric probes might plunge into Saturn or Neptune to assess the planet's chemical makeup. All this would be possible because nuclear electric propulsion lets mission designers devote more of their budgeted mass to scientific instruments and less to fuel.

Prometheus and JIMO could open up whole new types of missions for exploring the solar system. Says Ron Greeley: "For example, if one were to go to Saturn with a follow-on to Cassini, you could envision launching landers down on the solid parts of Saturn's moon Titan."

Designers could also forgo gravity-assist fly-bys to gain additional delta-V. The way it works now, scientists have to wait for the planets to get in a certain alignment before launching to the outer solar system via Jupiter. A delay on the ground can result in the narrow launch window being missed, and thus a wait for months or sometimes even years for the next alignment.

Beyond the maneuverability of the spacecraft, the extra power from nuclear reactors offers other advantages. "We want to have long-lived landers on the polar areas of Mars," Greeley says. Scientists suspect that if Mars has traces of life, past or present, they might be found at high latitudes. Exploring these areas hasn't been possible because they are in shadow much of the time, which rules out solar power. Scientists also would like to drill into the Martian ice caps, but that too requires extra power, says Greeley.

At Jupiter, JIMO will take the study of Europa and the other icy moons to a new level. Galileo's instruments were passive: They soaked up whatever feeble light and other radiation was reflected from the moons and converted them into images. With JIMO, scientists will be able to beam powerful radar signals at the moons, and the returning signals will be used to generate pictures, measure the altitude of varous features, and even see beneath the ice. Another idea is to melt the ice with a laser, making it possible to determine its chemical makeup. "That is the breakthrough—to get to active sensing of the outer planets," says Ray Taylor, NASA's overall system engineer for Project Prometheus and another Navy nuclear propulsion veteran.

In February, JIMO managers at JPL briefed U.S. spacecraft manufacturers on the conceptual design for the mission. NASA then awarded contracts to Lockheed Martin, Boeing, and Northrop Grumman to have them investigate designs for the Jupiter spacecraft. Newhouse wants the contractors to feel free to brainstorm. He warns against assuming that thrusters based on the DS1 technology will be the only answer. Another proposed ion thruster developed in Russia, for example, uses as its fuel the metallic element bismuth, which can be stored as a solid. At this point almost any propulsion design is still on the table.

For that reason, Newhouse says it would be foolhardy now to attempt a cost prediction for JIMO. "Come back in two years and I'll tell you the cost," he says. Everyone agrees that the technology will cost billions, however. "This could be the biggest procurement since the space station in terms of dollar value, so we have to do it right," Newhouse says. It's even possible, he concedes, that the contractors will tell him he's asking for the impossible. Then again, that kind of advice would not have deterred Prometheus.

Resto

The Champ | Fairey Firefly Mk. V

Eddie Kurdziel talks like he flies—fast. A former U.S. Navy aviator accustomed to the cockpits of carrier-based jets, he aims rapid-fire hangar talk at fellow pilots and sunburned airshow-goers alike—and it's all about his current passion: a beautifully restored Fairey Firefly.

Kurdziel is refreshingly egalitarian, a rare trait in a world of millionaires and their roped-off warbirds. At last September's Reno International Air Races, attendees could poke their heads into the Firefly's wheel wells, run their hands along its glossy gray finish, and even climb aboard—an honor seldom granted by a pilot whose aircraft is being considered for the coveted awards at stake at Reno. But the sneaker marks and fingerprints didn't matter: Kurdziel's Firefly, which was a Grand Champion at the Experimental Aircraft Association's AirVenture 2002 fly-in, won both the Rolls-Royce Aviation Heritage Trophy and, perhaps tellingly, the National Aviation Hall of Fame People's Choice Award.

The Firefly, a British long-range reconnaissance fighter, first flew in 1941 and entered service aboard the aircraft

carriers of the British Royal Navy's Fleet Air Arm in 1943—a year later, Fireflys were used to attack the German battleship *Tirpitz*. However, it was in the Pacific that the aircraft found its niche. With its four 20-mm cannon and muscular bomb load, the type was used to great effect against Japanese shipping and land targets. After the war, Fireflys were produced until 1956 and were operated by the Royal Dutch, Royal Canadian, and Royal Australian navies; Canadian and British Fireflys saw action during the Korean War. The Firefly, with its powerful engine and a radar operator/navigator in a second seat, had no exact equivalent in the U.S. Navy. Its versatility spawned both night fighter and anti-submarine versions.

Kurdziel began his project more than nine years ago, when he spotted an ad for a "60 percent restored" Firefly. He paid British warbird expert Ray Middleton's way to Australia to take a look. Middleton approved. Once all the pieces were shipped to the United States, Kurdziel, plus every volunteer he could persuade to help, worked out of a shipping container near Middleton's Fort

Eddie Kurdziel's ex-Royal Australian Navy Fairey Firefly spent nine years in the restoration shop (right) and today sports the stripes used in the Normandy invasion and later in the Korean War. The Firefly's huge wings tuck in for the cozy confines of an aircraft carrier (top).

TOP: CHARLES BROWN COLLECTION, RAF MUSEUM; LEFT: PAUL BOWEN; BELOW: COURTESY TIM FRIES

Collins, Colorado shop, laboriously matching each component to a Fairey parts list so it could be cataloged for later use.

Kurdziel learned that there are a variety of ways to approach a restoration. Many owners want a reliable aircraft that looks correct but may have modifications under the skin. The alternative is to demand that a restoration be correct throughout. The latter approach is difficult to follow with British aircraft, which use some components not common to U.S. aircraft.

The tradeoffs often start immediately behind the propeller, as with U.S.-owned Hawker Sea Furys, in which the original Bristol Centaurus powerplants are often replaced with widely understood Wright R-3350s—the same engine that powered the Boeing B-29. But a true British restoration extends to the small details, including rivets, bolts, and screws that are completely different from American fasteners.

"Eddie was unique in that he was interested in authenticity," Middleton says. "And we pushed him that way." The search for British hardware sent Kurdziel around the world and sometimes required him to borrow pieces from museums so they could be reverse-engineered.

Middleton and fellow restorer Tim Fries engineered a few exceptions for convenience and long-term reliability, such as an improved oil filtration system, but otherwise, the aircraft is as close as it can be to when it was mission-ready in the Australian navy.

Significant work was done to rebuild one of the Firefly's most distinctive features: Its huge Fairey-Youngman flaps, which made the heavy fighter docile enough to operate from a carrier. Another key feature, pneumatic brakes, is a rarity; many British warbirds flown today have been converted to use hydraulic systems. Kurdziel learned that authenticity required that he master new skills. "It was hard to get used to applying brakes from the stick during run-up instead of pushing the tops of the rudder pedals," he says.

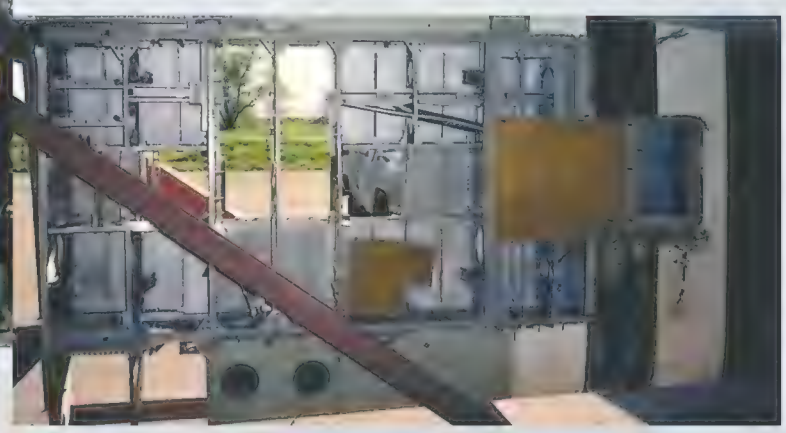
Kurdziel, who admits he has a Type-A personality, had trouble tolerating the restoration's sometimes unpredictable pace. "I figured I was paying a penance for something I did in a previous life," he says. "Maybe I wrecked one."

Middleton, who has worked on Spitfires and other British aircraft most of his adult life, good-naturedly dressed down his impatient customer. "Ray told me, 'The owners are just a transient thing. I've been maintaining these airplanes longer than you've been flying,' " Kurdziel says. Further clarity came from Kurdziel's girlfriend, who asked him if he'd ever considered that the aircraft was more important to the restorers than it was to him. The epiphany was complete—Kurdziel gave in to the Zen of the process and threw away the timelines.

Now, while he's on the airshow circuit and something goes amiss on the Firefly, Kurdziel knows his place: "I call Ray up and say, 'Your airplane's broken. What do I do?' "

—John Sotham

Kurdziel buttons up the Firefly's beastly 12-cylinder Rolls-Royce Griffon engine. A former U.S. Navy pilot, Kurdziel is today a top gun on the airshow circuit, where his Aussie fighter has bagged a number of coveted trophies for aircraft restoration.



The Firefly's pneumatic brakes were retained during the rebuild and are actuated from the control column, which has a distinctively British round grip (far left). A tired wing awaits sheet metal salvation (left). The restoration combined wings from two different Fireflys built in different years.

LEFT: COURTESY TIM FRIES (2); TOP: CAROLINE SHEEN

ZWRRW

WWBRZR!

HOW THE XF-84H THUNDERSCREECH BROKE THE NOISE BARRIER.

BY STEPHAN WILKINSON

It was the era of sounded-like-a-good-idea-at-the-time designs. Airplanes that took off straight up, hanging from enormous contra-rotating props or climbing a beanstalk of jet thrust. Jets launched from flatbed trucks, flung into the air by rockets. Inflatable airplanes. Flying wings. Tailless deltas. Jet seaplanes. Jet seaplane *fighters*. So there was nothing unusual about taking an early jet fighter, the Republic F-84 Thunderjet, and putting a propeller on it.

But wasn't aviation trying to get *rid* of propellers?

Never mind, we're going to drive this propeller with an enormous turbine engine—two engines, in fact, coupled through a common gearbox—and we'll spin it so fast that the prop tips will be traveling at 901 mph—Mach 1.18. At least the *prop* will be supersonic.

The result was the Republic XF-84H, a swept-wing, single-seat, T-tail turboprop that, at the time of its rollout in 1955, had the unhappy distinction of being the loudest airplane ever built.

The –84H had an otherwise honorable pedigree. The original straight-wing F-84 was named the Thunderjet to remind everyone that it was part of the Republic family that had begun with the World War II P-47 Thunderbolt. Among U.S. fighters, the F-84 was a first: Its slim, bud vase of a fuselage was wrapped around a slender axial-flow engine, in which the air's path is a straight line from front to back. (The earlier—and chubbier—centrifugal-flow engines compressed the air by whirling it outward.) The F-84's swept-wing follow-on, the F-84F, was tagged the Thunderstreak, which was followed by a reconnaissance version, the RF-84F, called the Thunderflash.

The XF-84H, however, was given an inglorious nickname by one of its test pilots: Thunderscreech.

"One day, the crew took it out to an isolated test area [at Edwards Air Force Base in California] to run it up," recalls Henry Beaird, a Republic test pilot at the time and one of only two men ever to fly the -84H. "They tied it down on a taxiway next to what they assumed was an empty C-47, but that airplane's crew chief was inside, sweeping it out. Well, they cranked that -84H up, made about a 30-minute run, and shut it down. As they were getting ready to tow it back to the ramp, they heard this banging in the back of the C-47." It was the crew chief, Beaird relates, knocked silly by the high-intensity noise and on his back on the floor of the –47, flailing his limbs. "He eventually came out of it," Beaird recalls.

"As long as you stood ahead of or behind the airplane," says Beaird, now 78 and flying Learjets, "it really wasn't so bad, but if you got in the plane of the prop, it'd knock you down." *Really?* "Really."

But there was a good reason to test the propeller: Early jets—the P-80, the F-84, even the vaunted F-86—were like overgeared vintage Ferraris. Put the thing in top gear and step on it and you may eventually do 150, but you'd be

Prop, swept wings, a huge T-tail—the XF-84H was one of a kind.

OPPOSITE: EDWARDS AIR FORCE BASE HISTORY OFFICE

forever getting there. The jets accelerated with aching slowness, so when they were loaded for bear—a fighter's natural state—they needed long runways. Short on concrete? Better leave some fuel and weapons home.

On landing, a turbojet pilot had to be very careful about speed control: Get a little too low and slow on final approach, cob the power to correct, and you might hit the ground before the engine wakes up and puts out enough thrust to accelerate.

Propellers were different. On a powerful fighter like the P-51, you had to feed in power judiciously, because if you firewalled the throttle, the entire airplane tried to counterrotate against the prop's torque. With a tractor propeller spinning clockwise (as seen from the cockpit), the airplane would turn hard left and plow straight off the runway. But compared to jets, propellers provided power right *now*.

The XF-84H was built for the Air Force's Propeller Laboratory at Wright-Patterson Air Force Base in Dayton, Ohio. Engineers there wanted to test supersonic propellers to see if they could get the best of both worlds—jet speeds and propeller responsiveness. "That didn't mean the airplane will run supersonic," Beaird cautions, "because with that big a prop disc up front, it's like a big speed brake. It meant that on the -84H, the outer 12 to 18 inches of the propeller were supersonic all the time."

That, of course, was the source of the horrendous noise. The Thunderscreech's engine ran at full speed all the time, and the propeller rotated at 2,100 rpm from startup until shutdown. "All you had to do was move the propeller pitch control to get power and you got it pretty instantaneously," Beaird explains. He thinks it might have gotten even louder with power, because he remembers he could hear it better where he lived, 22 miles away from the base, when the crew ran up the engine to full power.

"Edwards was worried that the noise of the airplane would break the windows in the control tower," he remembers. "The runway's about a mile from the tower, but they'd put blankets over the top of the shelf where the radios were, and they'd get up under their desks, under the blankets. Nobody ever actually recorded the decibels. I think they were afraid the measuring device might get broken."

"Oh, man, that noise was terrible," recalls Edward von Wolffersdorff, Beaird's crew chief. "You can't imagine," he adds with a groan. "I remember making my first ground runs with the thing, down on the main base, and I was wondering *Why are they flashing that red light at me over on the control tower?* It turned out they couldn't hear a damn thing over their radios, so they kicked us out and sent us over to the north base."

Most accounts of the XF-84H program specify that the propeller spun at 3,000 rpm, which would have resulted in the prop tips traveling at an incredible Mach 1.71. Extensive research and computation by John M. Leonard of the Rolls-Royce Heritage Trust (Rolls Aerospace currently owns Allison) indicate that an engine turning at 14,300 rpm driving a 6.8:1 gearbox, as the T40 did, would push the tips of a 12-foot-diameter propeller to a far more logical Mach 1.18.

Beaird agrees. "The tachometer indicated 3,000, but I'm not sure that was prop rpm. The tip speed was about 1.2 Mach, so what Leonard calculated is correct," he says.

A small shark's-fin-like control surface was added just aft of the cockpit to counter propeller forces on takeoff. Republic test pilot Henry Beaird could deflect the small but surprisingly effective surface to a maximum 45 degrees off centerline by turning a dial in the cockpit. Mounting the horizontal tail high atop the vertical fin was intended to keep it out of the hellishly turbulent flow of air from the prop.

The XF-84H opened up like a fisherman's tackle box, with a pair of speed brakes next to the jet nozzle and a ram air turbine that deployed from a compartment beneath the dorsal fin to provide systems power.

EDWARDS AIR FORCE BASE HISTORY OFFICE (2)

The airplane was not popular at Edwards and is to this day rumored to have caused several miscarriages. "It's hard working on a project like that when you know everybody's against it," von Wolffersdorff says. "Nobody wanted the damn thing. First the Navy backed out and then the Air Force canceled the project. A lot of people thought we were trying to go supersonic with a prop, but that wasn't true at all."

The Navy had gotten wind of the -84H and initially wanted in on the project, so Republic planned to build three—two for the Air Force and one for the Navy. But because the Navy canceled its order, only the first two made it out the door. The Navy originally liked the fast-turboprop concept because pure jets caused problems aboard carriers. The early catapults had a hard time accelerating fighters to takeoff speed, and even today on landing, standard procedure is to go to full power right at touchdown in case the tailhook misses the arresting wires and the aircraft has to go around. Jets are slow to spin up after a "bolter," as such misses are called.

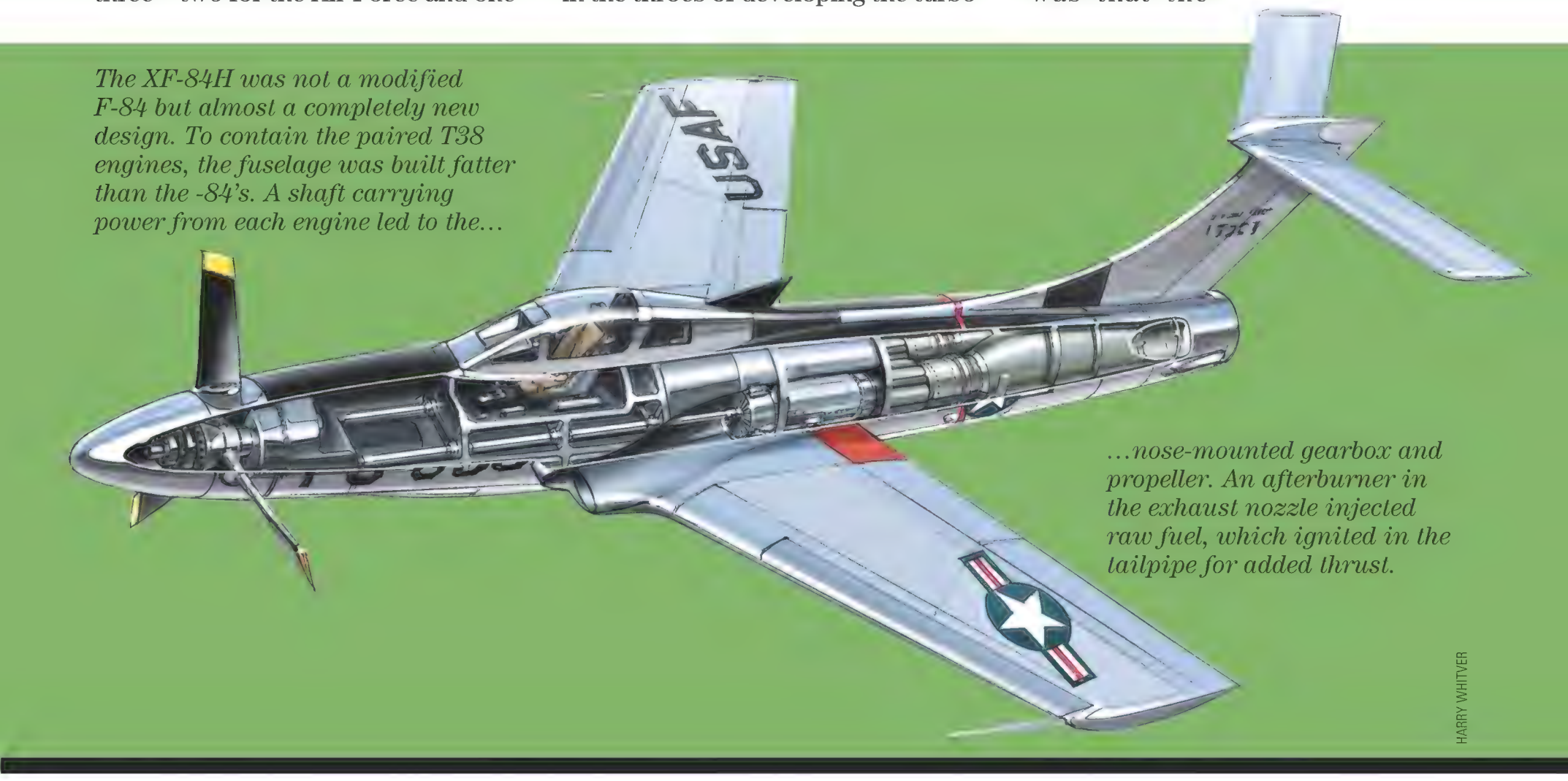
Three manufacturers were asked to provide experimental props for the -84H: Aeroproducts, Curtiss-Wright, and Hamilton Standard. In the end, only Aeroproducts stepped up to the plate, providing a stubby three-blade paddle prop, each blade about four times as long as it was wide. "It was a funny-looking propeller," Beaird recalls. "I think it was just one they happened to have available."

The Thunderscreech's Allison T40 engine was, even in the words of the company's own authorized history, *Power of Excellence*, "a monstrosity, a mechanical nightmare.... Allison was in the throes of developing the turboprop concept, and began probably 20 years ahead of where it should have been." The T40 was a pair of 2,750-shaft-horsepower T38s inside a common engine case. It was mounted behind the cockpit, where the F-84's Allison J35 turbojet had originally lived. Although the -84H's swept wings and main landing gear were straight off the RF-84F, its fuselage was almost entirely new, substantially modified to fit the big T40 engine. In fact, the airplane was so different from the F-84 that it was originally to be called the XF-106, a designation that eventually was given to the Convair Delta Dart.

During the mid-1950s, the T40 was the most powerful aircraft engine on the planet, putting out between 5,850 and 7,400 shp, depending on the model. Each of its T38s turned an 18-foot driveshaft that led to a big gearbox in the XF-84H's nose. Though the pilot couldn't see them, the shafts were spinning at stunning speed on either side of the cockpit, just under the floorboards. To stiffen the relatively flexible shafts, Republic installed numerous bearings along their entire lengths. One of the company's major concerns was that the driveshafts would overheat the bearings, so each one had temperature and vibration sensors, with meters and warning-light readouts on the glareshield directly in front of the pilot.

"We looked at the damn gearbox and thought *Jeez, that's gonna be a bear*," Ed von Wolffersdorff recalls. "And those shafts that ran past the cockpit on each side, boy, that made you pucker up just to think about it. We were expecting the worst, but they never gave us a bit of trouble.

"We did have some problems with the gearbox, but it was operator error," he adds. "You'd get the left en-



The XF-84H was not a modified F-84 but almost a completely new design. To contain the paired T38 engines, the fuselage was built fatter than the -84's. A shaft carrying power from each engine led to the... ...nose-mounted gearbox and propeller. An afterburner in the exhaust nozzle injected raw fuel, which ignited in the tailpipe for added thrust.

HARRY WHITVER

gine going first, then you'd engage its clutch and get the gearbox turning, drive the righthand engine back through the gearbox and get it going.... I was checking out another crew chief and told him to be careful, but he forgot to get the coolant oil flowing, and man, it just cooked one clutch."

Beaird says the starting procedure consumed half an hour: building up hydraulic pressures, establishing nominal electric power levels, and getting the proper green lights.

The driveshaft had high levels of vibration in flight, Beaird says. "It was very sensitive. If it got to where the vibration was so bad that I thought it was going to cause damage, they just left it up to me to decide whether to get out of the airplane"—he means eject, which he never did, but 10 of his 11 flights ended in premature or emergency landings due to vibration or prop-controller problems. "The only time it became a handful was when you got it out around 400 knots," he says. "The propeller governor [which controlled rotational speed] would start surging, and the airplane would roll rather violently." The entire airframe was trying to rotate around the propshaft, torquing like a big flywheel with wings.

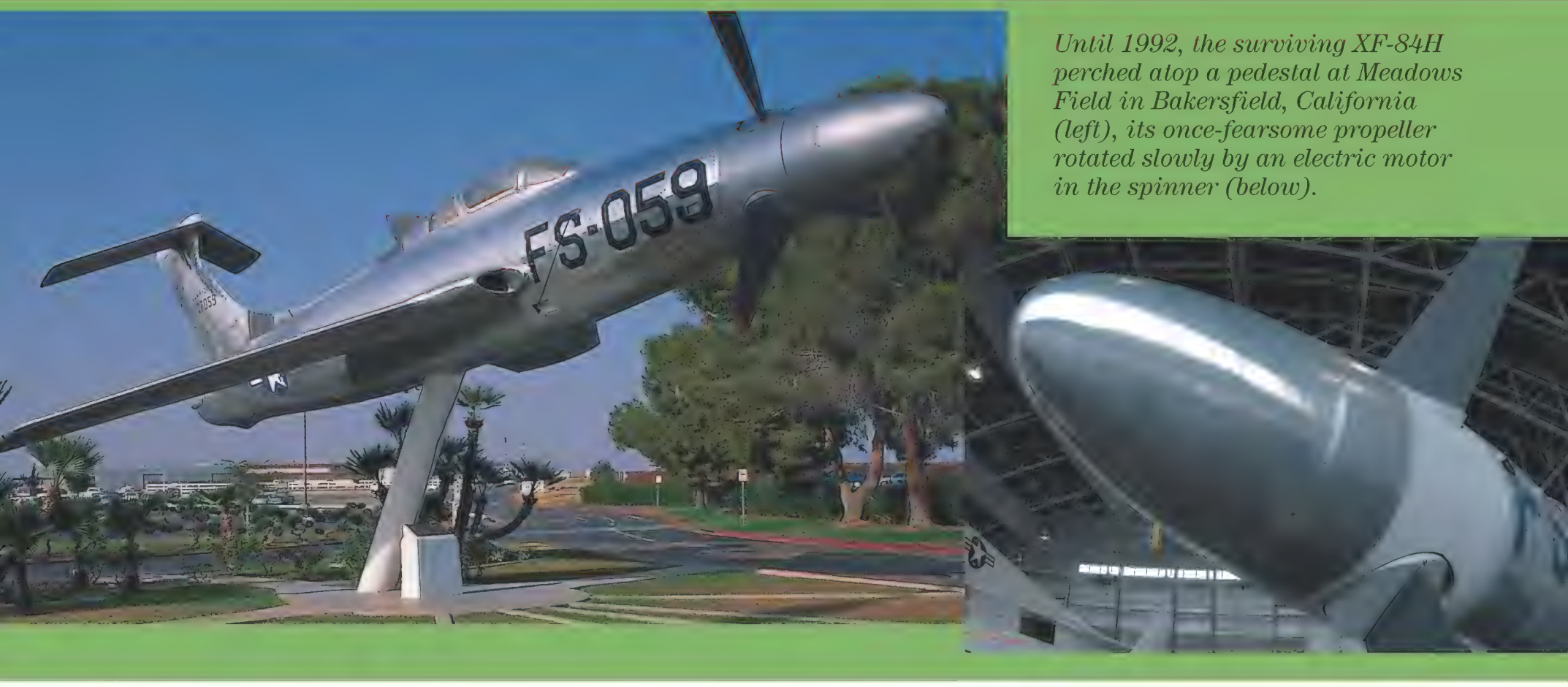
The late Lin Hendrix, a Republic test pilot who made a single Thunderscreech flight and was the only pilot to fly the second of the two airplanes, wrote in the August 1977 issue of the British magazine *Aeroplane Monthly* that Beaird, "who never swore, once said after an emergency landing, 'By jingo, that airplane is going to hurt somebody!' " Hendrix himself declined further opportunities to fly the 'Screech, telling Republic's chief engineer, Jim Rust, a muscular six-foot-four and 235 pounds, "You aren't big enough and there aren't enough of you to get me in that thing again."

Only a single XF-84H survives, the number-two airplane having been junked. The original test bed spent several decades at the entrance to Meadows Field, the Bakersfield, California municipal airport, where an electric motor in the spinner turned the prop at a stately 10 rpm, hardly hinting at the 'Screech in full song. In 1992, the old gate guardian got hangar space at the U.S. Air Force Museum in Dayton, Ohio. It has since been restored to display condition, and about a year ago was finally put on exhibit in the museum's experimental-aircraft hangar.

Robert Schneider and Darrell Larkin had both flown F-84s in the Ohio Air National Guard, and they assembled a team of volunteers who spent a total of 3,710 hours on the restoration. "You know you're in trouble when you have to have *pilots* working on an airplane," Schneider says, laughing, "but Darrell and I found a lot of retired chief master sergeants who'd been sheet metal guys and had other specialties. They're the ones who really did the work."

Aside from the supersonic-prop experiment, F-84s served as test bed aircraft for a considerable variety of other oddball projects. Schneider lists some of the reasons why: "It had a roomier cockpit than the F-86, and there were a lot of them made," he says. "It was a good-flying aircraft—a little underpowered but extremely strong. I had a midair collision once with another F-84, and we both kept flying and landed safely." A careless ground controller vectored Schneider and a flight of three other F-84s into a thunderstorm, and in the murk, the -84 to his right slammed into Schneider's airplane, its stabilator shearing off the front of his wing tank and then whacking the fuselage.

"The XF-84H was a hulk when we got it," Darrell Larkin says. "I think ev-



Until 1992, the surviving XF-84H perched atop a pedestal at Meadows Field in Bakersfield, California (left), its once-fearsome propeller rotated slowly by an electric motor in the spinner (below).

LEFT: CHAD SLATTERY; RIGHT: KATSUHIKO TOKUNAGA

ery kid who ever walked by that airplane in Bakersfield threw a rock up the tailpipe. I had to take a ton of stones out of there." But otherwise the airplane had never been vandalized, probably because it was on airport property and reasonably secure. "Except for the birds and other animals—prairie dogs, I don't know what," Larkin says. "There were nests everywhere. We had to do a lot of vacuuming, clean up a lot of dirt."

Its stubby but strident propeller got all the attention, but the XF-84H set some other precedents. The 'Screech was—and still is—the world's only turboprop with an afterburner, and visitors to the Air Force Museum can peek into the tailpipe and see all the spray bars and plumbing still in place.

Turboprops typically use their engine's tailpipe simply as a vent for gases that have already done most of their work, though the exhaust flow usually produces residual thrust as well—almost 1,300 pounds' worth, in the case of the Thunderscreech. The Navy wanted all the carrier-takeoff thrust it could get, so it had Allison fit the baby 'burner to the T40. The afterburner was lit only on the test stand, never in flight.

The -84H was also the first airplane to carry a "RAT"—a ram air turbine, which automatically deployed from a compartment in the dorsal fin and pinwheeled in the airstream to provide extra electrical and hydraulic power.

"The airplane had full-span ailerons whenever the gear was down, since the flaps became ailerons too," Hank Beaird says. "It took a lot of [additional hydraulic] power to move those surfaces if you had to move them in a hurry, and the RAT provided that. It would come out whenever the gear was down. That was one of the airplane's biggest contributions. We put that on other jets as well, particularly the F-105 [Thunderchief, the next in Republic's series], which also had a full-span aileron system."

Another XF-84H feature Beaird liked was its speed brakes, located all the way aft alongside the afterburner nozzle and opening to each side like flower petals. "Yeah, we learned a few things with that airplane," he says. "We put the same speed brakes on the F-105, but bigger—a four-petal arrangement. They made little or no trim change but tremendous drag. On the -105, you could put those things out at 1.8, 1.9 Mach and you'd just be standing on the rudder pedals, it slowed down so fast."

The two XF-84Hs flew less than 10 hours total. It may be the only U.S. Air Force aircraft that has never been flown by a military pilot. And to this day, nobody knows how fast a production F-84H would have gone. Republic made a wildly optimistic prediction of 670 mph, but neither of the two X-planes ever made it past 450 mph.

Still, at the time this was thought fast enough to make the XF-84H the fastest propeller-driven airplane in the world, a claim that can still occasionally be heard today. But in fact, that speed record was already held by the huge, four-engine, eight-propeller Soviet Tupolev Tu-95 Bear bomber, which, with its high cruise speed of 545 mph, remains by far the world's fastest propeller-driven aircraft.

The Bear was already in service in 1955, when the XF-84H made its first flight. When the big Soviet bomber first appeared, Western observers pegged its speed at 400 mph, based on what they had observed during the XF-84H project. Tupolev, however, had realized that the key to high prop-driven speed was long, multiple, slow-turning blades, contra-rotating for maximum efficiency, not a screeching little three-blade paddle.

LEFT: CAROLINE SHEEN; RIGHT: KATSUHIKO TOKUNAGA

In 1992, the U.S. Air Force Museum gave the Screech a roof over its tail (above). Museum director Charles Metcalf (left) poses for a photograph where no man dared to venture when the airplane was in full song.

Comment

Is It Worth the Risk? | by Richard Hauck

"I hope this thing doesn't blow up!" I remember having that thought as my crew and I accelerated through Mach 16 aboard the shuttle Discovery, 60 miles above the Atlantic.

Dick Covey, Dave Hilmers, Pinky Nelson, Mike Lounge, and I were strapped into our seats, upside down, blasting downrange inside 150 tons of hardware. It was September 29, 1988—just 20 months after the loss of *Challenger*. Was I scared? Many years before, I'd flown a machine that had blown up underneath me. You bet I was scared. But I also knew that a certain amount of fear is good, maybe even necessary, for sharpening one's awareness.

As a student at the Naval Test Pilot School in the early 1970s, I had a very disturbing dream one night. I dreamt that I was taking off in an A-4 Skyhawk. Right after takeoff the aircraft pitched up out of control, stalled, and plunged to Earth, where it exploded in a gigantic fireball. Even though I could see the billowing flames as if I were a bystander, I knew I was dead. And then I woke up, incredibly relieved to find myself safe in bed.

Lying there trying to get back to sleep, I remembered that I was on the flight schedule that morning—lined up to fly an A-4. I've never been a superstitious person, and I was determined to fly that flight. As I climbed into the cockpit I chuckled nervously to myself, eager to conquer the hobgoblins dancing around in my subconscious. Fortunately, the flight was routine—not a flicker of a problem.

The test flight I flew on July 23, 1973, on the other hand, didn't have such a happy ending. The aircraft was an RA-5C Vigilante, a Navy photo reconnaissance craft capable of speeds up to Mach 2. The test objectives were simple: Verify the Vigi's response to commands sent by an automated carrier landing system on the ground. Shortly after takeoff from the Patuxent River Naval Air Station in Maryland, I climbed to 1,200 feet and turned downwind to set myself up for a hands-off approach and landing. It was a hazy summer day with no definable horizon. Looking straight down, I could barely see the ripples on the surface of the Chesapeake Bay. Shortly after lowering the landing gear and flaps, I heard and felt an ominous *thrunk*. Several seconds later, my hair bristled as another shuddering sound shook the Vigi. Turning my attention back inside the cockpit, I saw a "RAMPS" warning light flash on, then off. This confused me: The light indicated that the engine inlets were somehow out of configuration, but at subsonic speed, the inlet ramps should not be moving at all. Then the left engine rpm gauge started unwinding rapidly, signaling a flameout.

The obvious question is: Why do humans take such risks, exposing themselves to palpable danger?

Looking up, I saw that the Vigi's nose had pitched down dangerously, to about 20 degrees below the horizon. The water was racing toward me, and the surface waves were now alarmingly well defined. I grabbed the ejection handle next to my left thigh and pulled. I was hurled upward by the rocket seat, and the next thing I knew, I was looking down at a fireball instead of water. I assumed the airplane had exploded on impact. Later, an investigation of the wreckage showed that the airplane had already been on fire when it hit the water. In other words, I had ejected after the fuel tank exploded.

Yes, as *Discovery* accelerated into orbit, I was scared.

The obvious question is: Why do people take such risks, willingly exposing themselves to clear, palpable danger? It isn't just astronauts. You might ask the same question of firefighters, police officers, and combat troops. Most have doubts, and are well aware of the risks inherent in their jobs. In fact, intelligent people will leave these professions when they recognize that their personal risk/reward ratio has tilted too far in the "risky" direction.

I'm reminded of a story about a Navy pilot who reached that point while making a night carrier landing. Landing a jet on the deck of an aircraft carrier at night and in instrument conditions is certainly the most demanding piloting task I ever had to cope with. By contrast, I had an easier time making my first dead-stick landing in a space shuttle: It was November 1984, and even though my heart was in my throat, the day was clear, the surface winds were benign, and the two-and-a-half-mile-long runway that I could see from 100 miles away didn't move an inch. It was tough, but it wasn't a night carrier landing.

Navy legend has it that on one inky night, approaching the ship, a pilot glanced out the left window and saw his wife and children sitting on the wing, staring at him with vacant eyes. Summoning all his courage, he focused intently on his instruments and brought his airplane down safely. Then he im-

entary

SCOTT ANDREWS

mediately strode down to his squadron commander's cabin and handed in his wings. Rather than disparage the man as a quitter, I admire him for recognizing his limits. It's very likely that many aviators have died because they didn't have the courage to admit to themselves—and to their colleagues—that they had reached that personal boundary.

Back aboard *Discovery*, as the shuttle thundered into orbit, I was able to stop the awful speculation that would naturally spill out if I let it. At that point, we astronauts were along for the ride, with no real options other than to enjoy the thrill. I had launched twice before on the space shuttle, but was acutely aware of a key difference on this flight, mission STS-26. This time I couldn't take comfort in the fact that NASA had never lost a crew to an inflight accident. *Challenger* was on all of our minds.

Still, I was convinced that this would be the safest shuttle flight ever, and had told my family so before the launch. NASA had spent the previous 20 months not only fixing the O-ring seal problem that had caused the *Challenger* accident, but studying in minute detail other shuttle systems to minimize the likelihood that another serious problem was lurking. The agency's safety and quality control programs had been overhauled. Astronauts had been placed in management positions to ensure that throughout the decision process, the crew's voice was heard.

For me anyway, there was a personal element to this sense of confidence. I was comforted knowing that my good friend Dick Truly had painstakingly overseen the *Challenger* reconstruction, and that Bob Crippen, who had commanded my first shuttle flight, was head of the review panel that had deemed our mission ready for flight just the day before. Tens of thousands of NASA and contractor employees had dedicated themselves to resurrecting the shuttle program. At the same time, I knew that there's no such thing as perfection. Our safe return was not guaranteed.

That *Discovery* mission was designed to be as benign as possible. Get up and back safely, proving that NASA was back in the spaceflight business. And so we did.

Now, in the wake of the *Columbia* tragedy, we once again hear it debated: Is spaceflight worth the risk? I've been asked that several times since February 1, but I think the question needs to be more precise. What risk are we talking about? As a taxpayer who shoulders part of the financial burden of this grand enterprise, you should certainly get a vote on how the money is spent. But are you questioning whether I should risk my own life? My family has a right to weigh in on that—after all, they have huge emotional, and even financial, stakes in my decision. But why should you get a vote? Please leave matters of risk up to the astronauts and their families. They've made their choice.

The families of the *Columbia* crew said it eloquently in a joint statement written under the most difficult of circumstances, days after their tragic loss:

"Although we grieve deeply, as do the families of Apollo 1 and *Challenger* before us, the bold exploration of space must go on. Once the root cause of this tragedy is found and corrected, the legacy of *Columbia* must carry on—for the benefit of our children and yours."

The authors of that statement are painfully aware that astronauts take risks. They also know the real rewards of participating in a great adventure, of advancing frontiers and serving one's country in the company of extraordinary colleagues. Only by taking such risks is society rewarded with increased knowledge and a sense of forward motion. And that, in the end, is what makes the risk worthwhile.

Richard Hauck flew on three space shuttle missions, twice as commander. He left NASA in 1989, and is now president and CEO of Axa Space, Inc., a satellite insurance company in Bethesda, Maryland.

GOOD WOOD

In a world of metal and composites, two Florida shops still carve propellers from birch and maple.

BY TOM HARPOLE | PHOTOGRAPHS BY CHAD SLATTERY

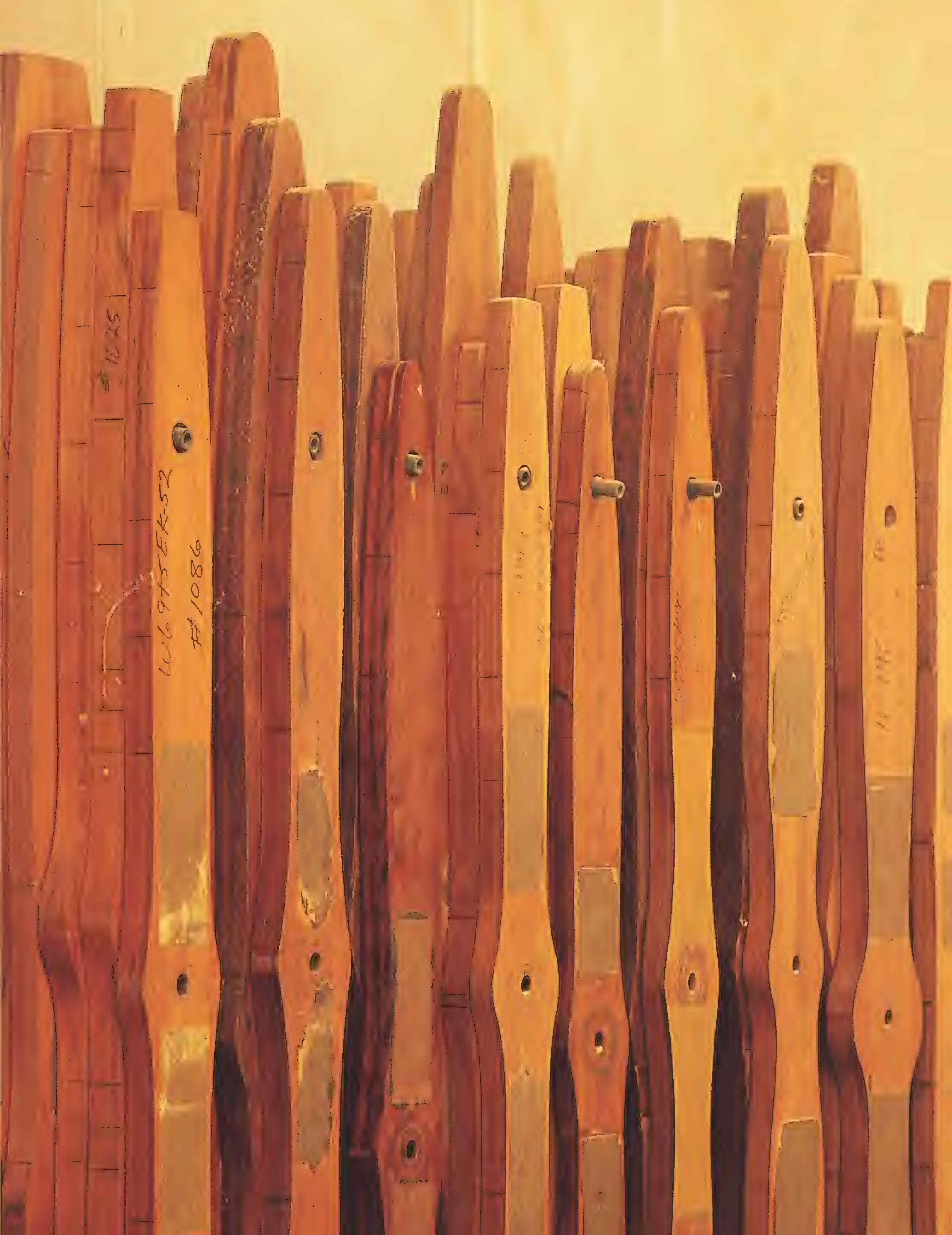
One summer day in 1928, Harry and Martin Sensenich took their propeller-driven farm wagon on its maiden flight, so to speak, hurtling down the narrow dirt roads of Lancaster County, Pennsylvania. It was a maelstrom of an outing, leaving in its wake stampeding livestock and a series of transgressions against the rules of the road. The next day, authorities banned the brothers from operating their go-devil on the Pennsylvania byways.

Having experienced the exhilaration of being propelled by pushing air, the Sensenichs sought another course. By that winter they had transplanted their engine and propeller to an ice sled, which they tethered by a hundred-foot hawser to a stout stake set in the frozen Susquehanna River. They enjoyed speeding around the circle until eventually the rope frayed, the sled catapulted into the brushy bank, and snow settled upon the remains of the boys' conveyance. Their newly purchased propeller was splintered into kindling. The Sensenich brothers (pronounced "Sen-sen-ick"), impecunious but ingenious, borrowed a drawknife and a spoke shave—tools used in making wagon wheels—and, encouraged by local aviators, began experimenting with the graceful compound curve of a propeller.

Seventy-five years later the company that bears their name has produced more than 450,000 wooden propellers—as well as thousands of metal props. The Sensenich Brothers Propeller Company meets almost the entire demand for Federal Aviation Administration-certified fixed-pitch wooden propellers in the United States. "We still carve about 4,000 props per year," says general manager Don Rowell.

Rowell's career with Sensenich spans a third of the company's history. He started when he was in high school, sweeping sawdust at the company's original location in Lancaster County. Rowell has performed every job in the prop-making process. He spent 10 years hand-carving more than 10,000 rough-cut hardwood blanks into perfectly balanced, laminated-wood props. In

Templates used to trace propeller outlines onto birch boards await woodworkers at the Sensenich Wood Propeller Company (opposite).



Master blades (above) will be mounted on a duplicating router by their squared-off tips and huge hubs to make rough profiles from layered boards called blanks. Sensenich general manager Don Rowell (right) eyeballs a completed 70-inch prop for a Piper J-3 Cub.

1994, Rowell, by then general manager of Sensenich, moved the wood prop shop to Plant City, Florida, to get closer to the market for a big chunk of its production: swamp boats, also called airboats. He provides 20 craftspeople with some of the best-paying jobs in the area, having trained them in skills that aren't taught at the local vo-tech.

On the majority of aircraft, metal and composite props have replaced wood, but, wooden propellers still own 10 percent of the aviation market. The demand derives from attributes including performance ("It's much easier to design the optimum wood propeller for custom aircraft," says Rowell; "Wood propellers inherently have less vibration"), price, and, in the case of vintage aircraft, authenticity—right down to the 1940s-vintage Sensenich decals that the company applies to the finished product.

"Wood makes sense," says Steve Boser, the design engineer at Sensenich. "Metal props are much more sensitive to engine vibrations. All props flex in flight, due to harmonics, the high-frequency oscillations excited by engine vibrations. Wood props damp out engine-induced vibrations by several magnitudes better than metal. But countless flexion cycles don't affect wood significantly, while metal props accumulate invisible flaws from vibrations and flexing.

"A wood prop is as good as it looks. We've had 30-year-old wood props come in that only needed refurbishing, cosmetics. And we've had wood props come back in two years that were unairworthy. It all depends on proper maintenance."

During World War II, when the Sensenich company employed 400 people and cranked out more than 5,000 propellers a week, wood was the only material the company used. Sensenich didn't begin producing metal propellers until the late 1940s. Metal props initially had a performance advantage over wood—because metal is so strong, metal props can be made thinner than wood and are therefore more efficient. But the benefits were obviated in the early 1950s by the design of a new airfoil for wooden propellers. Wood props traditionally had a flat backside, which worked well, but the thickness that was required to keep them from flexing cost some efficiency, measured by the percentage of shaft horsepower converted to thrust horsepower. Sensenich engineer Henry Rose designed a wooden-blade airfoil that was curved on both sides—now called the Rose "E"—which

brought wood prop performance within a few percentage points of the performance of metal props.

In performance, a few points make a huge difference. Formula One props, for instance, at 90 percent efficiency, propel air racers at 275 to 300 mph. "We get the physics from customers who tell us the engine power, prop diameter, and rpms [revolutions per minute], and we make a prop that has maximum efficiency at full power cruising at 7,000 feet," Boser says. "But it's still like choosing one gear ratio for a car."

Efficiency in fixed-pitch props is always a compromise: They either take off and climb well, or optimize the engine's horsepower at cruise, but they can't do both. Sensenich makes a high-speed target-drone prop that is rated 90 percent efficient for cruising at 300 mph, but the propeller's pitch is so inefficient at takeoff that a catapult is required to get the drone airborne.

Propeller pitch is determined by the ratio of forward speed to the propeller's rotational speed. Theoretically, a 41-pitch prop would move forward 41 inches along an imaginary line during the time it takes for the propeller to make a single revolution. Outfit identical Piper Cubs, one with a 46-pitch prop and the other with a 50: The 46-pitch, at 2,300 rpm, cruises at 85 mph. The 50, under the same conditions, cruises at 100 mph.

In addition to airboat props, a portion of the Sensenich production goes to uncertified, experimental, and amateur-built aircraft, and for powered paragliders and hang gliders. Steve Boser is a powered paraglider pilot, and he tests every new design the factory manufactures for the paraglider market, heading to a nearby cow pasture and flying in the sultry evenings.

John Monnet, an experimental-aircraft designer in Oshkosh, Wisconsin, who has sold more than 2,000 kit planes and 500 Sonex aircraft, uses wood props exclusively. "We've designed aircraft that use engines that run from 2,750 to 6,000 rpms," he says. "You can't safely cover that range with metal props. Wood is durable, experiences far less torsional vibrations, and we can experiment with different tuning of the prop. It costs a few hundred dollars for Sensenich people to change a computer program and carve a new pitch and diameter. It costs

General aviation aircraft take 40 percent of Sensenich's wood props, airboats take 20 percent, and display props, 10 percent. The biggest market niche the company supplies is unmanned aerial vehicles, which account for 30 percent.

From top: Charlie Brown selects the best of the bunch from a stack of eight-foot yellow birch boards, rejecting those with discolorations or knots. Rory Monroe operates a computer-numeric-controlled milling machine that shaves wood to convert a blank to a rough profile. Jesse Sims seals a prop by dipping it into a large tank of household wood sealer. This model 54JJ44 (54-inch length, 44-inch pitch) is destined for an 80-horsepower engine in a 150-mph Sonex homebuilt.

From top: Jose Mendez (at left) and Wayne Allen screw down 100 clamps in just 25 minutes to let the resorcinol glue set between the six layers of this blank for 18 hours. The blank will be used to produce props for Stinson 108s with Franklin engines. Darrin Grooms uses a 70-year-old duplicating router to carve a rough airfoil profile on a blank. Jesse Sims fastens on "tipping," a strip of brass that will protect the leading edges, with copper rivets and stainless steel screws.

thousands for recasting, grinding, and polishing a forged-metal prop."

General aviation aircraft take 40 percent of the company's wood props, airboats take 20 percent, and display props—for decoration only—10 percent. The biggest market niche the company supplies is unmanned aerial vehicles, the small recon and attack aircraft, which account for 30 percent. The niche is growing, due in part to the fact that ship-launched UAVs are designed to return to the ship and crash-land into a Kevlar net, breaking, it is hoped, only the propeller. "You've got a million-dollar plane, a $20,000 net, and a 300-dollar prop," Rowell says, adding with a grin: "Props are cheap." The Sensenich price range runs from the low-end UAV props to $3,000 for a 98-inch Stearman.

Business has been steady, and customers seem to accept that the process of making a wooden propeller may require a wait. "The last time we got caught up with orders was after September 11th, when the aviation world slowed down," Rowell says.

The craftsmen at Sensenich begin their workday at 6:00 a.m., switching on fans of all descriptions—including a couple of wooden four-footers built at the shop—to counter the torpid Florida air that wafts in from the loading dock.

At each station where the props are taken through another stage of development, there's a fan and a boom box. The ambient noise in the gymnasium-size building never lets up, a gnashing din of whines, grinding, chipping, and hammering that competes with rock, salsa, rap, bluegrass, and oldies blaring at the various workstations.

Props follow a spiral path around the factory floor, starting at the center of the building, where rough-sawed yellow birch planks, all one inch thick and random widths and lengths, are stacked on carts that crowd an area the size of a parking space.

Here at the center, inspector Charlie Brown sorts through the birch boards, which are harvested from New England tree farms. Before Brown begins making a stack, he has a specific propeller in mind. He balances each board on the edge of his hand, culling nearly half of them as he stacks up as many as 16 laminations, swapping ends so that heavy sides alternate. (A stack of five 0.75-inch-thick laminations is stronger than a solid 3.5-inch-thick piece of wood.)

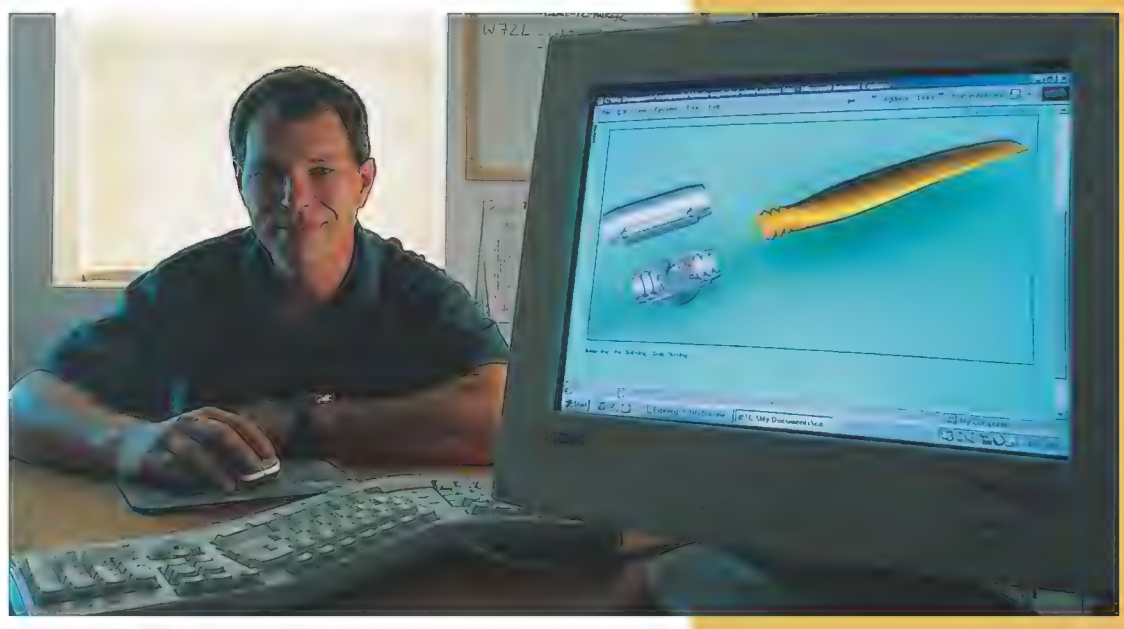
The shop, near the Plant City airport, resembles an industrial museum, with tools that haven't changed in 75 years. Not even

the glue has been improved in decades. Resorcinol has been the only adhesive used by Sensenich since "somewhere back in World War II," Rowell says. "We've never had a glue failure. If we tried to use some new glue we'd have to go through recertification. Way too expensive to replace something that has worked flawlessly for 50 years."

The purplish glue coats nearly every surface in a far corner of the factory where Jose Mendez and Wayne Allen are making up a blank for a 98-inch Stearman prop. The set-up time of the resorcinol, at 90 degrees, allows them less than an hour to apply the glue to each surface of the eight laminations and get the blank clamped. "It's no big deal," Mendez says. "We'll get it in 25 minutes." Twenty-two minutes later, the two have applied 112 C-clamps to the laminations. There is nowhere on the prop that they can insert a fist between clamps. Resorcinol drips down the terraced edges of the big blank in one-inch intervals. After the initial machine carving, the glue lines along the laminations of yellow birch will define the prop's curve from root to tip and provide guidelines for the master carvers to follow.

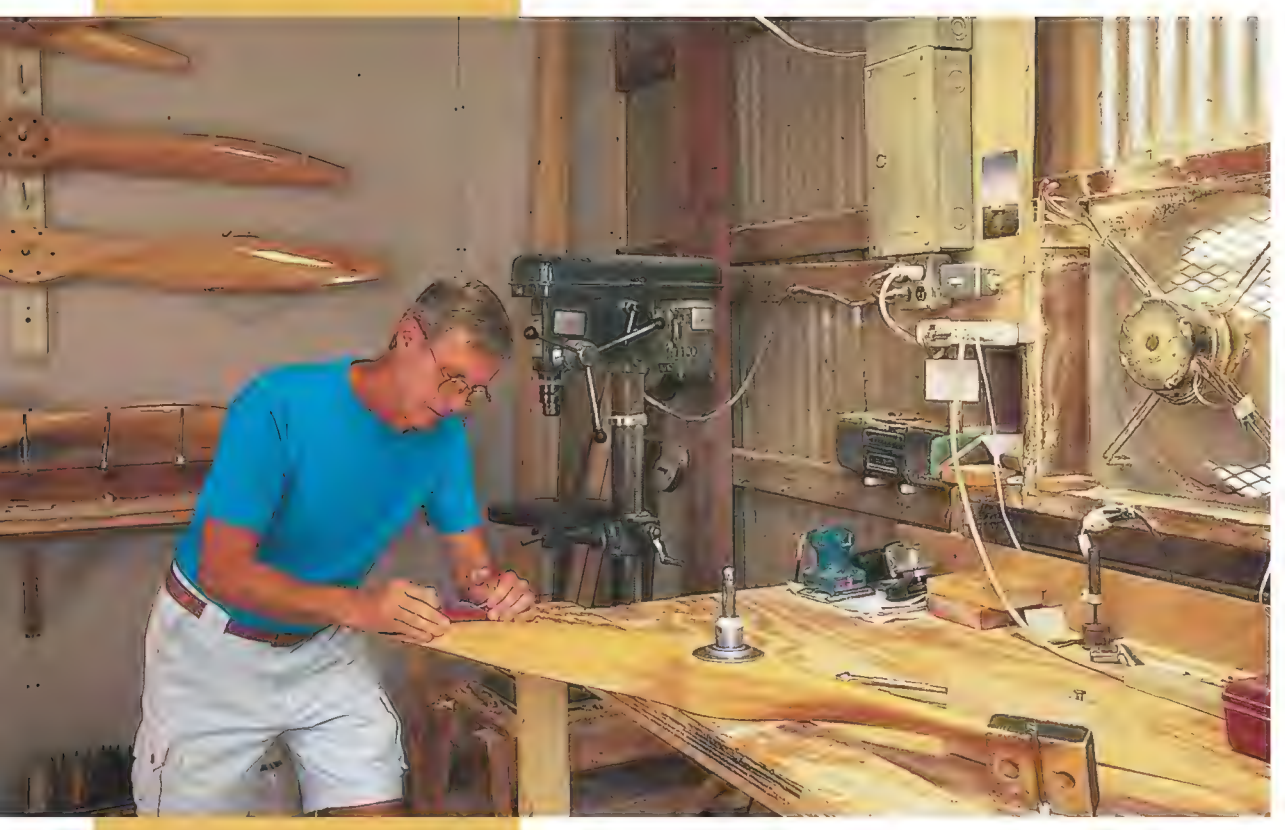
After letting the glue set for up to 24 hours, the workers rough-shape the blanks in a computer-controlled carving machine, or on the duplicating router, a 70-year-old machine designed by Martin Sensenich that rough-cuts laminated wood blanks into propellers. Like a three-dimensional key-cutting machine, the big router, modeled after a gunstock-duplicating machine, tracks the shape of a pattern prop and transfers the profile to the blank. When the blanks are rough-cut they are within 3/16 of an inch of their final shape. A worker carries the rough-cut blanks to a drill press, where a large hole is milled out of the hub, then a drill press is used to bore the bolt holes. The hub hole doubles as the fastening point for vises that are designed to allow the carvers to set the props at any angle they wish.

By 2:00 p.m., at the master carvers' station, it is 94 degrees in the shop, and Chris Thorpe and Ben Smith are bent over, scrutinizing a tiny area on a prop. They beckon Justin Bryant, a burly apprentice carver who moonlights as a mud wrestler. Bryant bends over and puts his face about a foot away from the blade, and three close-cropped heads hover within inches of one another as they stroke the spot with their palms and fingers. "Things you don't feel with your fingers alone you'll notice if you



Steve Boser (top) displays on his computer monitor an assembly diagram for an experimental model 72L ground-adjustable prop. "Wood makes sense," Boser says. "Metal props are much more sensitive to engine vibrations." Props for Pioneer unmanned aerial vehicles await inspection (left). The prop on a Pioneer (bottom) enables it to cruise at 92 mph at 15,000 feet, but the prop's pitch is so inefficient at takeoff that the UAV is usually catapulted or fitted with a rocket.

PIONEER UAV INC.



Ed Sterba custom-carves hard maple into props in his tiny workspace, producing three a week.

Sterba regards the first Wright brothers' propeller as a stunning achievement of calculus and craftsmanship. "Their propeller was easily as great a discovery as anything they had to learn," he says.

use your whole hand," Thorpe instructs Bryant. Their shirts flutter in the stiff breeze from the fan.

Thorpe turns to his workbench and picks up masking tape and a razor blade. Smith turns the fan off and Thorpe goes to work with the blade, chipping off a glue line that is an inch long and perhaps half the width of a toothpick. Smith makes a little masking tape dam and Thorpe dribbles some epoxy into the minuscule gouge in the prop.

Thorpe bends over his props in an unbroken curve from hams to head. Later he will wield an air-driven drum sander that is revolving at 1,800 rpm and sand down the epoxy patch to a .03-inch tolerance—the thickness of a piece of paper. The carvers also use the drum sanders to sand away the leading edge so that they can make another dam to fill with urethane for erosion protection on props that don't get protective sheet metal applied to their leading edges.

By early afternoon the carvers are ankle deep in shavings from countless strokes they pull with Stanley #64 spoke shaves. "This here is the heart of the prop carving business," Thorpe says, holding out a six-inch-long spoke shave with a two-inch blade centered between spoon-like handles. The way he holds it tells me he is not offering it for closer inspection. "Got to take care of what makes the truck payment," he says, cradling the tool in his palms.

When the drum sander's whine gives way to the soft scritching of overlapping spoke shave strokes at the carvers' station, Smith and Thorpe pass the time in blurted exchanges on topics as diverse as the taste and texture of wild frog legs versus farm-raised frogs and the heartbreaking error of feeding piglets a pickup load of rotten cantaloupes. "They couldn't digest the seeds and swelled up and croaked, but not like frogs," Thorpe notes. They exchange recipes for soft-tailed turtles. Most of the day, however, they are busy with a tricky bit of wood grain a few inches from their eyes, and they are absorbed into the swift strokes of their spoke shaves, and with sandwiching metal templates on the front and back of the props until they meet at a perfectly carved spot along its length.

Thorpe and Smith, arguably the two best prop carvers around, don't race each other or the clock. "The people who pay this kind of money for a propeller deserve something as nice as humanly possible," Smith says.

What's humanly possible, especially without the aid of computers and duplicating routers, is what Holmes Beach, Florida freelance prop carver Ed Sterba has been doing for 20 years. He is one of perhaps a dozen independent carvers in the country who advertise their non-FAA-certified propellers in the classifieds of aviation magazines.

Sterba, a lean, tanned pilot and sailor and single parent of three teenagers, also projects the contentment and pride that seems inveterate in woodworkers. Working out of a shop smaller than the Sensenich rough lumber stack, he makes three propellers per week. He keeps a library of hundreds of index cards on which he has recorded mathematical descriptions of the angles, thicknesses, curves, and pitches of hundreds of props at four to eight stations along their two blades. His power tools are a band saw, hand-held planer, drum sander, and a drill press that he built from mismatched parts and wood scraps. Working without templates, he relies on his eyes and two decades of standing over laminated-maple blanks clamped to a workbench the size of an ironing board. He balances a maple plank using a point like an old-fashioned tire balancer. Then he drills a hub into it and sketches lines along its length to guide him when he bandsaws the laminated planks into rough props. As he listens to the predictable cadences of NPR, he planes and sands away at the rough form until it looks like the propeller he wants.

Sterba regards the first Wright brothers' propeller, the one they carved in their Ohio

bicycle shop, as a stunning achievement of calculus and craftsmanship, as amazing as the airplane itself. "Their propeller was easily as great a discovery as anything they had to learn," he says.

His tiny shop is located in a row of commercial spaces that are rented by artisans: antique restorers, a couple of jewelry makers, a potter. He regards his work as a critical trade compared to the craftsmanship of, say, furniture or musical instrument making. "Lives are at stake," he says. "This is closer to boat building. But real artists can do things that I can't."

Art is amorphous by nature, and Sterba "repitches," or slightly adjusts the blades' angles, at no charge if they aren't as efficient or perfectly tuned to the aircraft's performance as possible. "That's the nature of experimental aircraft," he shrugs. It's also the nature of pilots who seek the ideal fixed-pitch prop: one that takes off and climbs taking advantage of max horsepower, but doesn't let the engine overspeed at cruise.

Like the Sensenich company's, Sterba's material costs are limited to wood, glue, leading-edge materials, and coatings. Sterba buys one-inch-thick maple boards from a local lumber dealer and uses random widths from two to eight inches wide to lay up laminated blanks. Like any prop maker, he strives for balance at every step of the process.

Back at the Sensenich factory, Don Rowell notes: "Everyone who handles these props can affect, for good or bad, the balance." After a prop leaves the master carvers, placing a paper clip on the tip, as it rests on the horizontal balance beam, would cause it to rotate out of level.

The master carvers move perfectly balanced props on to have the leading edge tipping applied: stainless steel and brass work that conforms to the twisting curve of the leading edge so closely and finely as to be barely palpable. Jesse Sims, who fabricates and fastens the sheet metal tipping, adds as much as 12 ounces of brass or stainless steel sheet metal plus the weight of as many as a hundred screws and rivets. He makes the sheets into trough-shaped pieces that wrap the edge for an inch and a half, then he clamps the metal onto the prop, adjusting a bungee cord so that it doesn't cover the holes he had earlier drilled for the screws and rivets that fasten the metal to the wood. Using a torch and solder, he drips molten lead into the bugled depressions in the edge, which he will then grind and polish until he achieves a fine sheen.

"The paint booth boys can change the balance with an extra coat of paint here and there, but these props have to be within a couple grams of perfect when I'm done," Sims says.

One afternoon at quitting time, I watched Sims punch his time card and walk by a rack of finished propellers on his way out. He paused to run his index finger down the polished brass edge of a Stearman prop with more than 100 rivets and screws fastening the bright brass to the leading edge. The tips of that prop, at 2,100 rpm, will travel at Mach .80—roughly 612 mph—without perceptible vibration for thousands of hours.

"These props are sculpture," I said.

Sims, nonplused, replied, "This is a production outfit." He plucked his cap off and scratched his sweaty gray thatch. "We fight tooth and nail to get these props perfect. We have keen eyes and hands here. Nothing gets shipped with an imperfection."

Thorpe and Smith are two of the best prop carvers around. "The people who pay this kind of money for a propeller deserve something as nice as humanly possible," Smith says.

One of Sensenich's biggest customers is the swamp boat industry. This Air Gator International hull (above) has a four-blade, 80-inch-diameter prop on a 540-horsepower marine engine, enabling the airboat to reach 70 mph in shallow water. A 1942 Fairchild PT-19 Army Air Forces trainer (left), now owned by Wayne Boggs in Plant City, Florida, wears a Sensenich wood prop, model W86RA-61, for authenticity, and the prop even has original Sensenich decals.

On October 22, 2002, 125 accomplished photographers set out to capture a day in the lives of men and women in the U.S. Army, Navy, Marines, Air Force, and Coast Guard—from generals to GIs, pilots to parachutists, missileers to MPs. The results appear in *A Day in the Life of the United States Armed Forces* (HarperCollins, May 2003).

Troops learn to avoid rope burns at the U.S. Army's Air Assault School in Fort Campbell, Kentucky (above) , where photographer Dick Swanson elected to remain aboard the helicopter they exited. In addition to learning advanced rappelling, soldiers at the school study combat assault, equipment rigging, and helicopter sling loading. Senior Master Sergeant Pat Schraufnagel (opposite, top) flashes two victory signs—or are those "air quotes?"—at jumpmaster Cadet Second Class Aaron Donne, a fellow member of the U.S. Air Force Academy's Wings of Blue demonstration team, as he deplanes over Colorado Springs at 17,500 feet. "They couldn't wait to get up in the air and out of the plane,"

recalls photographer David Butow. Marine Private First Class Jermaine Adams, aboard a CH-46E Sea Knight, mentally prepares for troop insertion drills over Okinawa (right). "We'd land," says photographer Torin Boyd, "[and] everybody would get off and secure the area. Then they'd climb back aboard, take off and circle around, and do it again."

Runway Models

Come Fly With Us! A Global History of the Airline Hostess

by Johanna Omelia and Michael Waldock. Collectors Press, 2003. 160 pp., $24.95.

COURTESY HARDING LAWRENCE/BRANIFF INTERNATIONAL

Before husky-voiced ennui became the norm, stewardesses were pleasant, pretty young women admired by girls and desired by men. It's easy to understand their universal allure; in a world of limited opportunity, airline hospitality paired the glamour and excitement of travel with, well, just a few rules about height, weight, marital status, stocking seams, gum chewing, cigarette smoking, pregnancy, tooth whiteness, nail polish, and the "willingness to retire between ages 30 and 32."

Less about mid-air comfort than about sex appeal, fashion, and gender expectations, *Come Fly With Us!* is pure popcorn reading; it takes no sides and makes no social arguments, only offering readers a delightful ensemble of facts, photos, and advertisements from which they can draw their own conclusions about the history of the airline hostess. In a well-designed and enjoyable coffee table book, Johanna Omelia (a former fashion editor) and Michael Waldock (an aviation enthusiast) trace the evolution of "fly girls" from airborne nurses to sex kittens to safety officers.

Of course, the subject owes much of its appeal to airlines' outlandish efforts to cater to men's fantasies. Well before Hooters Air, there was no shortage of male-passengers-only flights and provocative clothing like micro-miniskirts and gold lamé paper party dresses (stewardesses used scissors to adjust the hem). Press shots of chirpy flight attendants are fascinating, not only for the fashions in which they were uniformed, but also as evidence of what could be gotten away with. Pacific Southwest Airlines' 1970s hot pants and go-go boots seem like good clean fun compared to Malaysian Airlines' 1980s geisha-like floral sarongs and advertising which claimed its stewardesses' "desire to please and serve stems from a natural hospitality." On another note, it could be argued that no uniform has ever surpassed in sheer loveliness United's ultra-mod 1960s skimmers.

For all the glamour, *Come Fly With Us!* remembers to touch on the serious: the risk of death when the industry was young and flying was more perilous, the recent phenomenon of air rage, the Civil Rights Act which allowed men into the profession, and legal victories that permitted married women—and pregnant women—to keep their jobs. Even past the age of 32.

—Sam Goldberg is an associate editor at Air & Space/Smithsonian.

Hypersonic: The Story of the North American X-15

by Dennis R. Jenkins and Tony R. Landis. Specialty Press, 2002. 264 pp., $39.95.

When I was 12 and fighting the unbearable Kansas summer, I'd spend my days in the air-conditioned library reading encyclopedias. They had no beginning and no end; I could pick up a volume at random, begin at any entry, and spend the day in the cool air, always learning something.

I was reminded of that summer when I read *Hypersonic*. To call *Hypersonic* a "book" is to do it injustice; it's really an encyclopedia, and a comprehensive one at that—no concise kiddie's *World Book*, but

an *Encyclopedia Britannica*—with more than 550 photos, many in color. All you have to do is turn to a random chapter and start reading to get a story.

The X-15, of course, was nothing less than the fastest, highest-flying airplane ever to leap off the drawing board. After the barrier-breaking X-1 and its ilk, the National Advisory Committee for Aeronautics (NASA's predecessor) called for a rocket-powered craft that could eventually reach 250,000 feet above Earth's surface—almost 50 miles. The NACA invited nine manufacturers to submit designs, but only a few stepped up to the plate: Republic, veteran X-plane builders Bell and Douglas, and X-newbie North American. According to the authors, the organization settled on North American's design when teams of NACA advisors graded it superior in "performance, technical design, research suitability, development capability, and cost" to the plans put forth by other companies.

Eventually three X-15s were built. Pete Knight reached a top speed of Mach 6.70—4,520 mph—in the modified X-15A-2 on October 3, 1967. This came four years after NASA's Joseph Walker reached the program's peak altitude of 354,200 feet, or 67 miles, on August 22, 1963, in X-15-3. Walker and 11 other X-15 pilots were eventually awarded astronaut wings for their forays past the edge of space, and though every Mercury flight bested the altitude, flying the X-15 could be considered just as dangerous—if not more deadly. In the rocketplane's decade-long history two pilots died; by contrast, there were no casualties in the Mercury and Gemini programs.

This is a no-nonsense book that leans toward the technical. If it had been available 30 years ago in a small Kansas town's library, maybe I wouldn't have as much trivia about movies and farming rumbling around in my head.
—Phil Scott, author of five books, lives in Manhattan.

FOR THE KIDS

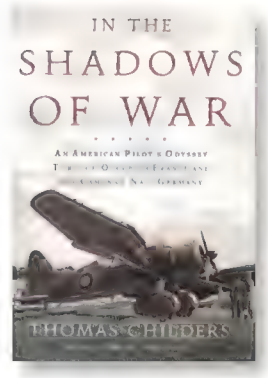
The Noisy Airplane Ride *by Mike Downs; illustrations by David Gordon. Tricycle Press, 2003. 30 pp., $14.95.*

A picture book that does a surprisingly good job of acquainting children with the causes of inflight thumps and rattles—or soothing the nerves of older, more anxious travelers. Downs' uninspired rhymes seem at times disconnected from the *wusshhhh*s (the air vents), *ker-ooshs* (a flushing toilet), and *ert-erts* (wheels touching down) found in Gordon's smoggy, subdued illustrations. Youngsters, however, will delight in sharing this onboard listening—and noise making—experience with parents.

In the Shadows of War: An American Pilot's Odyssey Through Occupied France and the Camps of Nazi Germany

by Thomas Childers. Henry Holt, 2003. 443 pp., $27.50.

As the Second World War slips deeper into the past, personal accounts become more infrequent, increasingly leaving the war to the professional historian. And then there is this wonderful book.



Childers is himself a historian, but he is also a superb writer. Witness this sketch of a French agent being spirited to England for training: "Pierre sat in the blackness of the plane, numb with cold and lost in thought, as the engines droned and everything he loved slid away beneath him." (Childers' earlier history, *Wings of Morning*, so impressed the late Stephen Ambrose that Ambrose borrowed some of it without credit to plump up his lame best-seller, *The Wild Blue*.)

Shadows tells the story of U.S. pilot Roy Allen, shot down over France in June 1944. In his attempts to evade capture, he meets up with a brave young teacher in a girls' school, chain-smoking *résistants* in a Paris safe house, and a Belgian betrayer; finally he ends up in the stinking hell of the Buchenwald concentration camp.

In a postscript, Childers argues that his book is "a work of historical nonfiction," but in truth it's a nonfiction novel—re-created fact with a bit of poetic license—in a style that makes us privy to thoughts, conversations, and scenes that were never written down.

Pierre, the French agent, also takes the hard road to Buchenwald: "Even now, shivering in the clammy barracks, to think of [Mimi] and their nights in the room in Nangis brought a fleeting smile to his face." Perhaps. But unlike Allen, Pierre dies in the camp. "*Vive la France!*" he shouts at the end—a cry I doubt was reported by the men who shot him.

Though these be inventions, they're also the product of 10 years of research. The story rings true and should be read.
—Daniel Ford writes history and fiction, and is the author of Remains, *a novel about the Flying Tigers of World War II.*

Unlocking the Sky: Glenn Hammond Curtiss and the Race to Invent the Airplane

by Seth Shulman. HarperCollins, 2002. 272 pp., $25.95.

Good for Seth Shulman. His book about Glenn Curtiss has arrived at the right time—the centennial of the Wright brothers' first powered flight—to remind us that another inventor was at

BRIEFLY NOTED

Virtual Apollo: A Pictorial Essay of the Engineering and Construction of the Apollo Command and Service Modules *by Scott P. Sullivan; foreword by Tom Hanks. Apogee Books, 2002. 128 pp., $17.95.*

Meant for hard-core Apollo buffs, this impressive display of down-to-the-washer draftsmanship is quite a departure from its encyclopedic series predecessors. Colorful if awkwardly laid out, *Virtual Apollo* reveals the intricate, multi-layered design of the spacecraft (but not the lunar lander) and explores the functional relationships of some of its three million components. Photos and factoids supplement spotty text, but it's really the hundreds of computer-rendered schematics that tell the story.

least as important as the Wrights to the development of the airplane in the United States. Too bad Shulman felt he had to demonize the Wrights in order to make Curtiss seem more heroic.

We can all agree that the Wrights were not at all times charming. Shulman merely has to report the facts to show how waspish they were in their patent dispute with Curtiss. One nasty detail: The brothers deliberately filed their suit as the first international air meet was held in Rheims, France. Curtiss, the only U.S. participant, had to work hard to focus on the competition. The suit's timing was an especially dirty trick since it resulted in Curtiss' wife being the one who was served papers in his absence.

On the other hand, the episode around which Shulman organizes his book could be no great source of pride for Glenn Curtiss either: the Smithsonian Institution's 1914 recruitment of Curtiss to reengineer and fly Samuel Langley's aerodrome, which, on its second flight attempt nine days before the Wrights' success, had plunged straight into the Potomac River. Langley, Smithsonian Secretary in 1903, hoped to claim the first flight of a heavier-than-air machine; the Institution hoped Curtiss' efforts would prove that Langley's invention had been airworthy all along. A sympathetic biographer, Shulman writes that "the Curtiss-Smithsonian group can perhaps be faulted for an excess of zeal—as well as an indisputable conflict of interest in the aerodrome affair."

Shulman's book conveys the energy and optimism of Curtiss and his colleagues in the New York town of Hammondsport, and transports the reader to a time when success in aviation was by no means assured. For a more complete (and very readable) biography, readers should turn to C.R. Roseberry's 1972 *Glenn Curtiss, Pioneer of Flight*. But for a lively collection of formative scenes from Curtiss' life (despite the somewhat tedious expressions of outrage over the Wrights' attempts to profit from their invention), *Unlocking the Sky* is a good choice for any centennial of flight reading list.

—Linda Shiner is the executive editor of Air & Space.

Sled Driver: Flying the World's Fastest Jet, Centennial of Flight Limited Edition

by Brian Shul. Gallery One Publishing, 2003. 170 pp., $427.

The first edition of Brian Shul's *Sled Driver* (see Reviews & Previews, Apr./May 1992) is considered one of the finest books about the SR-71 Blackbird, if not the most beloved and desired. Twelve years after its 1991 publication, it still sells for well over $200 on eBay. In it, the former Blackbird pilot takes you into the world of his spyplane, introduces you to the support crews, explains in laymen's terms how the aircraft works and why it can be difficult to fly, and expresses the range of emotions he felt driving the Sled—a name affectionately bestowed by its pilot corps.

After four wildly successful printings and the subsequent folding of original publisher Mach 1, Shul's own Gallery One has taken *Sled Driver* in a new direction, and the differences are remarkable; the first edition looks like a sales brochure in comparison with the newer incarnation's fresh design and superior printing. Gone are the excess white space and grid-like layout typical of the early 1990s' sparse, to-the-point aesthetic. Designer Daniel Salcedo's decision to recast the book in a larger, wider format allows larger photographs to breathe and sing and for Shul to expand the text.

Thanks to glossy paper and better scanning, photographs that were dull and flat in the original book now pop off the page with vibrant color and clarity. Some of Shul's self-portraits in the cockpit get a bit repetitive, as do the glamour shots Shul took from T-38 chase planes of the jet against mountain ranges. Behind-the-scenes photographs are more interesting. Two particularly effective images show the legendary SR-71 fuel leak under a wing (its tanks' skins don't fit together tightly except when heated to flight temperatures) and a static J-58 engine on full afterburner at night. Silhouettes of the Blackbird's unique shape cutting through the dusk and dawn really capture the full majesty of the SR-71. The Limited Edition is also augmented by new images from renowned aviation photographers George Hall and Eric Schulzinger (both of whose work has appeared in *Air & Space/Smithsonian*).

CAMERON DAVIDSON

Sled Driver's presentation has been reworked, too. The book is accompanied by a flight patch, a numbered certificate of authenticity, and a rigid black slip cover featuring a gold etching of the jet as seen from above. The binding—made from the same material as the slip cover—features a laminated print of Shul's first ever and favorite shot of the Blackbird in flight: a backlit Blackbird ascending from a sullen gray thunderstorm to refuel. As a bonus, each of the 3,500 copies' opening page carries an identification number and the signatures of the author; Walter Watson, his reconnaissance systems officer; Robert Gilliland, the first SR-71 pilot; and R. Edward Yeilding, who set a coast-to-coast speed record on the Blackbird's final flight.

This book is an over-the-top tribute to the SR-71 from a pilot who loved it, but at $427 (to match the now-declassified compressor inlet's maximum temperature of 427 degrees Celsius) it is not a purchase you make lightly.

—Cameron Davidson is a freelance photographer and a frequent contributor to Air & Space.

Rocket Dreams: How the Space Age Shaped Our Vision of a World Beyond

by Marina Benjamin. The Free Press, 2003. 256 pp., $24.

As a child, Marina Benjamin idolized the Apollo astronauts, learned arcane trivia about the crews and their missions, and fully expected that she would soon vacation on Jupiter. Thirty years later, she set out on a pilgrimage "demanding to know why the future had not unfolded as promised." The result, an exploration of the imaginative legacy of the Apollo missions and a smattering of projects she feels were inspired by the lunar landings, is both frustrating and rewarding.

A chapter devoted to her attendance at a Roswell, New Mexico UFO festival, for example, could easily have been deleted. The legend surrounding the alleged flying saucer crash site has been written about extensively, and it seems a shame to devote so much space in the narrative just to conclude that the celebration of Roswell serves as "a hedge against having to relinquish a fundamental yearning for contact."

Elsewhere the book focuses on tangible (versus symbolic) programs, so it's puzzling that just a few paragraphs are devoted to the Mars Pathfinder mission and its charismatic rover, even though Benjamin regards it as "a wake-up call to thousands of people who hadn't shown the slightest interest in space for decades."

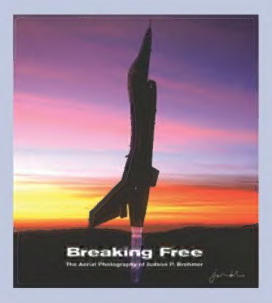
The best part of the book is a profile of the founders and a few of the 3.5 million subscribers of SETI@home, a free software program that analyzes radio signals from outer space for signs of intelligent life. The program allows researchers to borrow computing time from underemployed computers of everyday citizens; it has so far identified more than half a billion signals for follow-up study. This is the creative legacy of Apollo at its best, declares the author: ordinary folks sharing in the exploration of space. (Visit *setiathome.ssl.berkeley.edu* to participate.)

Surprisingly, Benjamin makes no mention of the International Space Station (or, for that matter, the earlier Skylab station), and the shuttle program is dismissed for its "routine" missions. Eventually, Benjamin makes a "reluctant peace with the Space Age's passing" and accepts the rise of the Information Age in its stead. While *Rocket Dreams* provides a few nice insights, it ultimately fails to deliver.

—Rebecca Maksel is an assistant editor at Smithsonian magazine.

BRIEFLY NOTED

Breaking Free: The Aerial Photography of Judson P. Brohmer *edited by Alessandra Brohmer and John Wagoner. Thin Air Publishing, 2003. 300 pp., $70.*



This collection of Judson Brohmer's work is narrated by pilots who maneuvered the photographer into place for air-to-air shots before his death two years ago. A 90-minute companion DVD features the F-22, X-35, B-2, aerobatics in an Su-21, and more.

CALENDAR

May 31 & June 1
Mid South Charity Airshow. Millington Municipal Airport, TN, (901) 263-6983.

June 5–8
World War II Heritage Festival. Richard I. Bong World War II Heritage Center, Superior, WI, (888) 816-9944.

June 6–8
World War II Weekend. Mid Atlantic Air Museum, Reading Regional Airport, PA, (610) 372-7333.

June 6–July 31
International Aviation Art Exhibit. United States Air Force Museum, Wright-Patterson Air Force Base, OH, (937) 255-8046.

June 13 & 14
EAA Chapter 200's Gathering of Eagles World War I Fly-In. Gardner, KS, (913) 788-5435.

June 14
Seminar: A History of the U.S. Navy's Lighter-Than-Air Fleet. American Airpower Heritage Museum, Commemorative Air Force Headquarters, Midland, TX, (915) 563-1000, ext. 2259.

June 14 & 15
Great Smoky Mountains Southeast Regional Aircraft Modeling Expo. Tennessee Museum of Aviation, Sevierville, TN, (866) 286-8738, ext. 24.

June 15–18
Reunion: International Birddog Association. Gillespie County Airport, Fredericksburg, TX, (830) 896-7604, *www.L-19BowWow.com.*

June 20–22
Centennial of Flight Festival and Fly-In at Wilbur Wright's Birthplace. New Castle, IN, (765) 478-5726.

July 11–13
Cape Girardeau Heroes and Legends Air Festival. Cape Girardeau Regional Airport, MO, (573) 334-6230.

July 17–20
Vectren Dayton Airshow. U.S. Air and Trade Show, Dayton International Airport, Dayton, OH, (937) 898-5901.

Organizations wishing to have events published in Calendar should fax press releases two months in advance to (202) 275-1886 or mail them to Calendar, Air & Space/Smithsonian, *MRC 951, PO Box 37012, Washington, DC 20013-7012.*

CREDITS

Masters of the Straight Deck. Paul Corrigan flew combat missions over Korea in 1952 and ended up spending 30 years in carrier aviation. His novel, *Last of the Aerial Gunfighters*, will be published by First Books in August.

Tandem Jump. James E. Dearing is a retired General Motors engineer.

Sticks for Hire. While reporting this story, Mark Huber flew with Matt Jackson in Howard Keck's converted Douglas A-26 and is delighted to report that nothing happened.

Fairford Sketchbook. Roger A. Mola writes frequently for *Air Shows* magazine.

Home-Grown Simulators. Matthew Stibbe ran a computer games company for 10 years; he now writes about aviation, business, and technology.

To Snatch a Sabre. Ralph Wetterhahn is a former F-4 Phantom pilot and the author of two books: *Shadowmakers* (Carroll & Graf, 2002), a novel set in Vietnam, and a history, *The Last Battle: The Mayaguez Incident and the End of the Vietnam War* (Plume, 2002).

Dan Zoernig uses scale models, digital photography, and computer manipulation to produce artwork reminiscent of traditionally created paintings.

How Things Work: Infrared Countermeasures. Sam Goldberg is an associate editor at *Air & Space.*

NASA Goes Nuclear. Ben Iannotta is an aerospace journalist living in the Florida Keys.

Restoration: The Champ. John Sotham is an associate editor at *Air & Space.*

ZWRRWWWBRZR. Stephan Wilkinson restores and writes about automobiles.

Good Wood. Tom Harpole wrote about the would-be pilots of Buran, the Russian space shuttle, in the Dec. 2002/Jan. 2003 issue.

FORECAST

In the Wings...

The Hmong Air Force
To the U.S. military command, the war in Laos was a CIA sideshow to the action in Vietnam. To the Hmong pilots the CIA trained, it was a last stand to protect their home, and they fought like tigers.

COURTESY BILL LAIR

Hmong leader Vang Pao, trailed by CIA officer Bill Lair, greets villagers in 1960s Laos.

Missed Approach at Kai-Tak
Now that Hong Kong's famous airport has closed, can the flying club based there keep the legends alive?

Space Garden
If we're ever going to travel to Mars, we need power, propulsion, and plants.

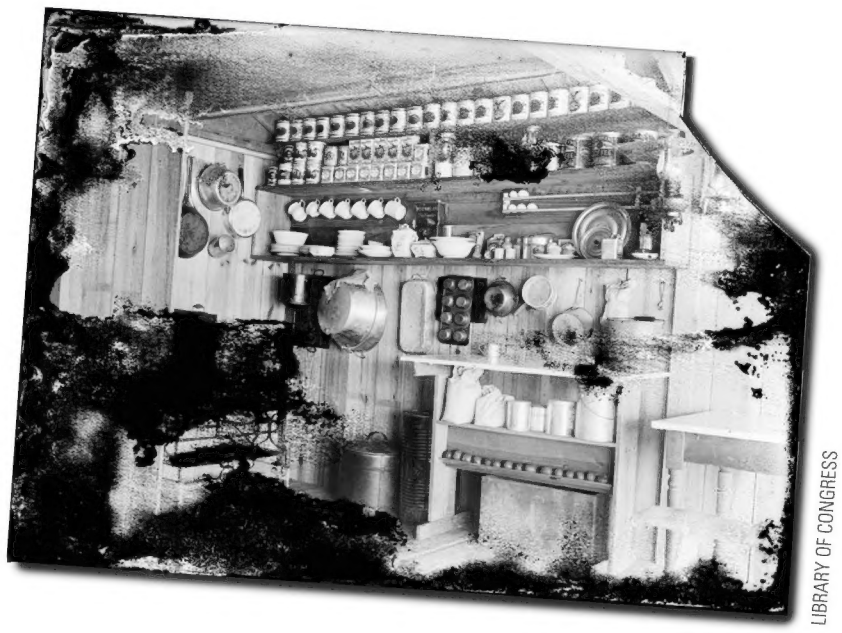
State Secret: The Trade War
The commodity: the de Havilland Comet. The time: post-World War II. The fear: technology transfer to the Communists. The combatants: former allies.

Of Tri-motors and Travel Airs
To awaken the country to the possibilities of the airplane, the Ford Motor Company sponsored national air tours between 1925 and 1931. This fall, a nonprofit foundation will reprise the act to awaken the country to the classic airplanes that flew the original tours.

ON THE WEB SITE

www.airspacemag.com

For more about the rivalry between the North American F-86 Sabre and the MiG-15, visit our Web site. You'll find a list of airshows where the MiG-Sabre Dogfight Team will be performing this summer, museums where you can view one or both of the fighters, links to Web sites that tell the story of the Korean air war, recommendations of books about the airplanes and of models to fly or display—even a line on buying your own, flyable F-86. (It's not cheap.)



LIBRARY OF CONGRESS

The tidy kitchen in the Wrights' revamped shed included room and board for mice.

"In Any Kind of Weather"

Last issue's excerpts from *The Papers of Wilbur and Orville Wright, Volume One, 1899–1905* (McGraw-Hill, 2001) described the initial flights of the 1902 glider and the brothers' work with the vertical rudder. In the following passages, Orville writes about revising the rudder, connecting it to the wing warping mechanism, and making an astounding number of successful glides.

Orville Wright's diary B, Sept. 27, 1902
At 11 o'clock last night I was awakened by the mouse crawling over my face. I found on getting up that the little fellow had only come to tell me to put another piece of corn bread in the trap. He had disposed of the first piece.

Oct. 3
While lying awake last night, I studied out a new vertical rudder.

Oct. 6
Will took order for groceries and sundries to Kitty Hawk after breakfast. He returned with a large mess of bluefish and spots which the men at the Kitty Hawk Life Saving Station had given him. We completed the change in the vertic. tail, which we have reduced to one surface of 6 ft. area, and which is now operated in conjunction with the wing tips, turning toward the wing with the smaller angle of incidence so as to give it more resistance, and thus allowing the wing with the larger angle, to rise more quickly.

The smart little mouse was found dead under trunk.

Oct. 11
The wind cut several feet off the top of the Big Hill, and is filling up, or blowing away, the ponds about camp. Wind 60 miles per hour for 2 minutes, accord. to Weather Bureau.

Orville to Katharine Wright, Oct. 23
Since [brother] Lorin was here and has probably told you all the news from camp, I haven't thought it necessary to write very often, but I don't like the idea of that roaring big supper you are going to get up for us next Wednesday night getting cold before we get there Thursday, so I write to advise postponing it to Thursday, at least, for we might possibly not get home before Friday morning.

The past five days have been the most satisfactory for gliding that we have had. In two days we made over 250 glides, or more than we had made all together up to the time Lorin left. We have gained considerable proficiency in the handling of the machine now, so that we are able to take it out in any kind of weather. Day before yesterday we had a wind of 16 meters per second or about 30 miles per hour, and glided in it without any trouble. That was the highest wind a gliding machine was ever in, so that now we hold all the records! The largest machine we handled in any kind [of weather, made the longest dis]tance glide (American), the longest time in the air, the smallest angle of descent, and the highest wind!!! Well, I'll leave the rest of the "blow" till we get home.

Moments & Milestones is produced in association with the National Aeronautic Association. Visit the NAA Web site at www.naa-usa.org *or call (703) 527-0226.*

LOGBOOK

Awards/Events

A new helicopter attractive for both civil and military applications has been selected by the National Aeronautic Association to receive the **Robert J. Collier Trophy** for 2002. The Sikorsky S-92—the only helicopter to be certified under the federal government's latest standards for transport-category rotorcraft (Federal Aviation Regulation Part 29)—was singled out for the award because it incorporates multiple improvements in safety, operating cost, and traveling comfort, thus offering potential users—whether common carriers or the armed forces—enhanced opportunities to place helicopters in service. Because of its many technical advances, the S-92 more than meets the Collier's criteria as the greatest achievement in aeronautics or astronautics in the United States for the preceding year. The trophy will be presented at a formal dinner on June 10, 2003, in Arlington, Virginia.

The Civil Air Patrol, the U.S. Air Force auxiliary best known for its search-and-rescue duties, has been selected to receive the NAA's **Frank G. Brewer Aerospace Education Trophy** for 2002. Established in 1943, the award recognizes "significant contributions of enduring value" in the field of aerospace education. The CAP won the trophy for more than a half-century of leadership in educating young people about the opportunities available in aviation and spaceflight. The trophy was presented at the annual National Congress on Aviation and Space Education meeting on April 4 in Cincinnati.

Nominations

Nominations for the **Katherine & Marjorie Stinson Award for Achievement** will be accepted through July 31. It is awarded to a living woman for an enduring contribution, a meritorious flight, or a singular technical development in aviation, aeronautics, or space.